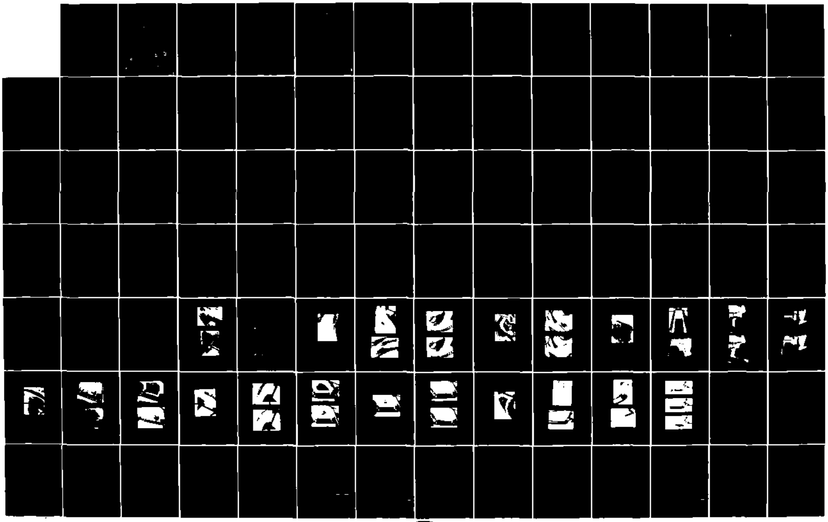
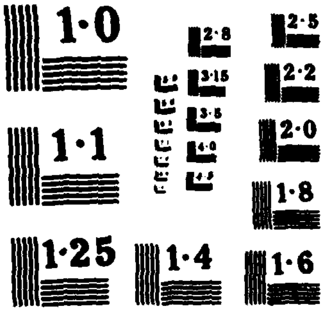
AD A146 974 BONNEVILLE SECOND POWERHOUSE COLUMBIA RIVER OREGON AND WASHINGTON HYDRAUL..(U) ARMY ENGINEER DIV NORTH PACIFIC BONNEVILLE OR DIV HYDRAULIC L.. W CONBERE AUG 84 1/3

UNCLASSIFIED TR 137 1 F/G 10/2 NL




1·0
2·8
2·5
3·15
2·2
3·5
2·0
4·0
1·1
1·8
1·25
1·4
1·6

REPRODUCED AT GOVERNMENT EXPENSE

(8)

HYDRAULIC MODEL
INVESTIGATION

TECHNICAL REPORT NO. 137-1

Bonneville Second Powerhouse Columbia River, Oregon and Washington

AD-A146 974

SPONSORED BY
U. S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT

CONDUCTED BY
DIVISION HYDRAULIC LABORATORY
U. S. ARMY CORPS OF ENGINEERS
NORTH PACIFIC DIVISION
BONNEVILLE, OREGON

AUGUST 1984

US Army Corps
of Engineers
Seattle District

3 October 1984

SUBJECT: Technical Report No. 137-1, "Bonneville Second Powerhouse, Columbia River, Oregon and Washington" - Hydraulic Model Investigation, August 1984

Plates 42, 43, 44, 45, 46, 47, 50, and 51 of the subject report have been reprinted to improve the quality of the original prints. The attached pages should replace similarly numbered plates in the report.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report No. 137-1	2. GOVT ACCESSION NO. A146 974	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Bonneville Second Powerhouse, Columbia River, Oregon and Washington Hydraulic Model Investigation		5. TYPE OF REPORT & PERIOD COVERED Final Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Engineer Division, North Pacific Division Hydraulic Laboratory Bonneville, Oregon 97008		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer District, Portland P.O. Box 2946 Portland, Oregon 97208		12. REPORT DATE August 1984
		13. NUMBER OF PAGES 141
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hydraulic models
Bonneville Dam
Columbia River
Second Powerhouse
Tailrace channel
Approach channel
Navigation locks

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A second powerhouse at the existing Bonneville Dam project was constructed to take advantage of additional upriver storage provided through treaty agreements with Canada. Hydraulic model studies were accomplished to evaluate hydraulic performance with various powerhouse locations. A new navigation lock is proposed for the project. Although the lock was not studied in this investigation, a primary powerhouse design consideration was that the second powerhouse location must not conflict with the logical location of a new navigation lock.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

A 1:100-scale model was used to study flow conditions in the forebay and tailrace of the powerhouse and to evaluate the effect of the powerhouse on existing fishway and navigation facilities. Three powerhouse locations were studied in the model; however, the final design consisted of an eight-unit powerhouse located on the north (Washington) shore. Tests indicated that raising the tailrace invert to elevation -10 could not be justified due to excessive power loss which would occur with this condition.

Numerous modifications to the design of the power unit draft tube exit and tailrace runout were tested in 1:80- and 1:40-scale single-unit models. These studies were accomplished to investigate the potential for detrimental upwelling in the vicinity of the fishway entrances.

PREFACE

Hydraulic model studies necessary to the design of the Bonneville second powerhouse were authorized on 2 April 1968 by the Office of Chief of Engineers at the request of the U.S. Army Engineer District, Portland (NPP). The studies were conducted at the North Pacific Division Hydraulic Laboratory during the period from May 1968 to May 1982 under the supervision of Messrs. H. P. Theus (retired) and P.M. Smith, Directors of the Laboratory. This report was prepared by Mr. William Conbere, Hydraulics Section, U.S. Army Engineer District, Seattle.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
miles	1.609344	kilometres
feet per second	0.3048	metres per second
cubic feet per second	0.02832	cubic metres per second
pounds (mass)	0.4535924	kilograms
tons	907.185	kilograms

BONNEVILLE SECOND POWERHOUSE, COLUMBIA RIVER,

OREGON/WASHINGTON

Hydraulic Model Investigations

PART I: INTRODUCTION

The Existing Project

1. The Bonneville Dam project is located at the head of tidewater on the Columbia River about 146 miles* above the mouth of the river (figure 1). The Oregon/Washington State boundary lies along the main Columbia River channel dividing the project between the two states. At the dam site the river is divided into two channels by Bradford Island. The spillway dam is constructed across the north (or main) river channel, and the original powerhouse was constructed across the south channel. Bradford Island forms an earth levee between the two structures. The navigation lock is located in the south abutment; fish attraction and transportation facilities are placed at both ends of the spillway dam in the north channel and across the face of the powerhouse in the south channel. An additional fishway extends from the forebay pool between the navigation lock and the Oregon shore downstream to Tanner Creek which empties into the Columbia about a mile below the dam.

The Proposed Project

2. The signing of the Canadian treaty agreements leading to the construction of Canadian projects for upriver storage of summer freshet flows and the development of the Pacific Northwest/Southwest Intertie dictated both enlarged power developments at the lower Columbia River projects and an increased peaking mode of operation.

---

* A table of factors for converting U.S. customary units to metric (SI) units is shown on page iv.

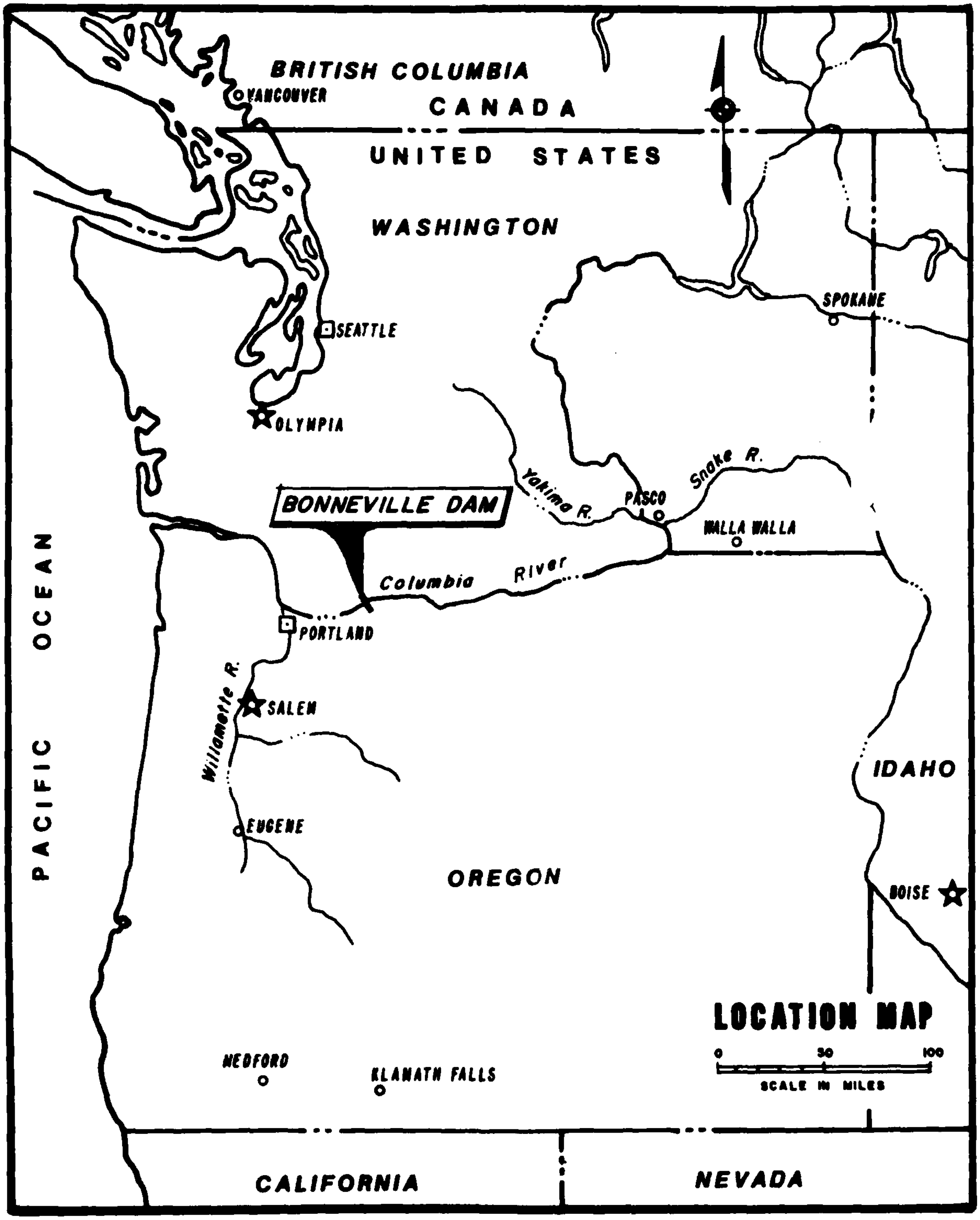

BRITISH COLUMBIA
VANCOUVER
CANADA
UNITED STATES
WASHINGTON
SEATTLE
OLYMPIA
SPOKANE
Yakima R.
PASCO
Snake R.
WALLA WALLA
BONNEVILLE DAM
Columbia River
PORTLAND
Willamette R.
SALEM
EUGENE
PACIFIC OCEAN
IDAHO
BOISE
OREGON
LOCATION MAP
0 50 100
SCALE IN MILES
MEDFORD
KLAMATH FALLS
CALIFORNIA
NEVADA

Figure 1

A second Bonneville powerhouse was proposed as part of a plan to accommodate these developments. Since the existing navigation lock is considered substandard relative to the more recent upriver lock developments, one criteria of the proposed project is that no second powerhouse location be selected that pre-empts the logical location of a new navigation lock. The project layout with the final-design second powerhouse is shown on plate 1.

Purposes of the Model Studies

3. The primary purposes of the model studies were to (1) confirm the suitability of the site chosen for the second powerhouse, (2) study flow conditions in the forebay and tailrace of the second powerhouse, (3) study the effects of the added units on existing fishway and navigation facilities, (4) investigate the future site of a proposed navigation lock, (5) study the effects of excavation on flow conditions at the proposed and existing locks, and (6) aid in the location of entrances and exits of any new fish facilities that may be required. Within the limits of the capabilities of the model, the effects of revised powerhouse operation on flow conditions in the downstream river channel and characteristics of stilling basin flow with revised spillway operation were also studied.

PART II: DESCRIPTION OF THE MODELS

Comprehensive Model

4. A 1:100-scale model was constructed to provide hydraulic data needed for the selection of a second powerhouse site and a possible new navigation lock location. The model reproduced 4.6 miles of the Columbia River between River Miles (RM) 142.3 and 146.9 and included the 18-bay spillway on the north (Washington) shore and the existing ten-unit powerhouse on the south (Oregon) shore. The channel and overbank areas were constructed of concrete molded between templates that conformed to the best-available survey data. The navigation lock, spillway, stilling basin, and powerhouse were constructed of waterproofed wood; all structures were calibrated independently to pass the correct discharge at controlled gate openings. Hydraulic roughness was created with roughened concrete surfaces, rock chips, crushed rock, and small boulders. Tailwater depth was controlled by adjustable tailgates on either side of Pearce Island; tailwater elevation was controlled at gage 9 (plate 3) according to tailwater curves supplied by NPP. Discharge into the model was supplied by a recirculating system and was measured by calibrated orifices in the supply lines. Velocities and flow directions were obtained with standard laboratory procedures. A remote-controlled model towboat with an overall length of 608 feet, a width of 80 feet, and a barge displacement of 14,200 tons was used to assist in evaluating navigation conditions in the approach channel.

Power Unit Models

1:80-Scale Model

5. The model consisted of a plywood flume with the powerhouse constructed of waterproofed wood at one end. Only the section of draft tube downstream from the elbow was modeled in detail. The remainder of the unit model was a simplified representation that

established the correct f' w pattern in the draft tube. Discharge into the model was supplied by a recirculating system and measured with a calibrated orifice. Flow was introduced directly into the powerhouse unit; an adjustable tailgate was used for tailwater control. A stilling bucket and electronic point gage were used to measure water surface elevations. Much of the data acquired consisted of sketches of the boil and flow conditions downstream.

1:40-Scale Model

6. The model consisted of a single powerhouse unit in a flume. Except for the wheel, all features of the unit (intake passages, scroll case, stay vanes, wicket gates, discharge ring, and complete draft tube) were modeled. The Kaplan blades and hubs were omitted from the model. The model was constructed with plastic, fiberglass, waterproofed wood, and plywood in a brick flume with a glass observation window. Discharge into the model was supplied by a recirculating system and measured with a calibrated orifice. Flow was controlled with wicket gates to reproduce forebay elevations. Initial tests were made with parallel sides in the flume to simulate an interior unit. Later tests were made with the left wall reconstructed to duplicate the end of the proposed powerhouse. A stilling bucket and electronic point gage were used to measure water surface elevations. Flow conditions were recorded on a closed-circuit TV system and then sketched.

Ice and Trash Chute Model

7. A 1:20-scale model was used to evaluate design of the ice and trash chute. Water was supplied to the model by recirculating systems and measured by means of V-notch weirs and calibrated orifices in the supply lines. Tailwater elevations were controlled by an overflow gate. The model was constructed of wood and plastic.

Model Similitude

8. The accepted equations of hydraulic similitude based upon the equivalence of the Froude Number in the model and in the prototype were used to express mathematical relations between the dimensions and hydraulic quantities of the model and prototype. General relations for transference of model (M) data to prototype (P) equivalents are as follows.

Dimension	Ratio	M:P	M:P	M:P	M:P
Length	L_r	1:100	1:80	1:40	1:20
Area	$A_r = L_r^2$	$1:10^4$	1:6,400	1:1,600	1:400
Velocity	$V_r = L_r^{1/2}$	1:10	1:8.94	1:6.325	1:4.47
Discharge	$Q_r = L_r^{5/2}$	$1:10^5$	1:57,243	1:10,119	1:1,789

PART III: MODEL STUDIES OF EXISTING CONDITIONS

Comprehensive Model Verification

9. Initial verification of the comprehensive model was based on bank and channel topography constructed according to hydrographic surveys taken in 1947, 1958, and 1963 and river gage data obtained in 1968 and 1969 for model verification purposes. Verification of the model with this data was satisfactorily completed for the reach upstream of the project prior to beginning any tests described in this report. However, the gage data could not be reproduced in the model between RM 144 and the structures (RM 145.5) due to major changes which occurred in the riverbed between the time of the latest survey and the time the gage data were obtained. A new prototype survey of the unverified portion of the model and new gage data was obtained in 1969. The model layout with the updated survey data and the gage locations is shown on plates 2 and 3.

10. Model water surface profiles at the gages along each bank downstream from the structures are shown on plates 4 and 5 for four discharges ranging from 125,050 to 372,870 cfs. These profiles are superimposed on profiles of prototype gage data and show a maximum variation of 0.4 foot at two gages (T-1 and TW) adjacent to the structures; the observed prototype and model data at all other gages were within 0.2 foot.

11. Although satisfactory verification of the upstream portion of the model was achieved with the original hydrographic survey information, the 1969 survey showed increased depths in the powerhouse forebay. The results of tests involving forebay excavations for south shore powerhouse sites D and E (made prior to the 1969 survey) are satisfactory for comparison with test results of the north shore powerhouse sites.

Existing-Condition Base Test

12. A base test using the old survey data was made with river discharges of 100,000, 200,000, 300,000, 460,000, and 800,000 cfs. Flow distribution is shown on plates 6 through 10. Except for data collected near the mouth of Tanner Creek, base test information was observed upstream from the structures.

13. Existing flow conditions make navigation somewhat difficult in the approach to the upstream entrance of the lock. Flow to the powerhouse is drawn obliquely across the lock entrance, and velocities in the approach channel are high. The combination of these conditions makes it difficult for tows to maintain steerage while decelerating to enter the short upstream approach to the lock.

Powerhouse Tailrace Velocities

14. Velocities and flow patterns downstream from the existing powerhouse for four discharges from 143,400 to 510,000 cfs are shown on plates 11 through 14. The highest velocities occurred with the 143,400-cfs discharge; the formation of several small eddies was also evident. With the three greater discharges, velocities were lower and the eddies were smaller or nonexistent. In all cases, good downstream flow existed just outside the limits of the eddies.

PART IV: SITE INVESTIGATIONS

Site D Powerhouse and Navigation Lock

15. The structures for Site D consisted of a six-unit powerhouse adjacent to the south end of the existing ten-unit powerhouse with a new enlarged lock (80 by 675 feet) to the south of the new powerhouse (photograph 1 and plate 15). Tests were made to determine the effects of a variety of forebay excavation and fill plans on head losses at the powerhouses and on navigation approach conditions. Tests were made on five Bradford Island excavation plans (plates 16 and 17), three Eagle Point excavation plans (plate 18), and fill plans for four navigation-lock upstream approach channels (plate 19). Additionally, studies were made of two different downstream entrances to the approach channel and the removal of Picture Rock and Boat Rock.

16. To accommodate the increase in discharge (from 141,000 to 272,000 cfs) with the new powerhouse, additional forebay excavation was necessary. Fifteen different configurations of forebay excavation plans were tested, and the resulting water surface elevations and powerhouse channel head losses are summarized in tables A and B. Flow conditions with Bradford Island Excavation Plan 1 (plate 16) were unsatisfactory because the alinement and extent of the Bradford Island excavation did not adequately provide for the additional powerhouse discharge, and high-velocity flow continued to follow the deeper, old river channel. Lock approach velocities were increased over the existing condition, and the higher velocities persisted for a considerable distance into the lock approach which essentially decreased the length of approach available for deceleration of a tow. Tests with Bradford Island Excavation Plan 2 (plate 16) and Eagle Point Excavation Plans 1 and 2 were similarly unsatisfactory. Bradford Island Excavation Plan 3 (plate 17) reduced the island to the minimum size that was feasible without changing the

existing fish ladder; excavation was to elevation 40*. With this plan but excluding excavation at Eagle Point, velocities in the lock channel with both powerhouses operating varied from 4 to 7 fps with river discharges of 300,000 to 600,000 cfs. Eagle Point Excavation Plans 1 and 2 did not decrease the velocities in the lock channel, although head losses between gages 1 and F-2 were slightly reduced at 600,000 cfs.

17. As navigation conditions did not improve by excavating Eagle Point, it was evident that the control was in the powerhouse channel--primarily in the section just upstream from the north lock guide wall. Bradford Island Excavation Plan 4 increased the channel area by lowering the forebay invert to elevation 20. This excavation plan produced good flow conditions. Head losses in the powerhouse channel were minimized, eddy losses at the powerhouse units were eliminated (except for eddies caused by a remaining portion of the existing lock), and satisfactory conditions for navigation existed in the upstream approach to the lock. Extensive excavation of Eagle Point was not needed, but some rounding of the point (Eagle Point Excavation Plan 3) would provide better conditions for navigation at 600,000 cfs.

18. Bradford Island excavation was limited to the size shown in Plan 5 (plate 17) due to concern that the small portion of the island remaining after Plan 4 excavation might permit serious seepage through the island, possibly leading to its eventual loss. The Plan 5 shape provides downstream flow at the fish ladder exit (so that fish are led upstream away from the powerhouse) and minimizes eddies at existing powerhouse units 7 through 10. The Eagle Point Excavation Plan 3 (plate 18) was installed to improve navigation past the point. With Bradford Island Excavation Plan 5 and Eagle

* All elevations are in feet to NGVD.

Point Excavation Plan 3 installed in the model, alternative fill plans for four navigation-lock upstream approach channels were tested. The test results, based on a comparison of conditions with no fill and the largest fill (to elevation 40), indicated that fill had little influence on velocities in the navigation channel (plate 20). A test was made to determine if any hydraulic benefit would be derived by the removal of Picture Rock and Boat Rock. The test results indicated there was no benefit obtained and that the rock islands acted as turning vanes and appeared to improve flow conditions to the powerhouse at 600,000 cfs. Removal of the rocks resulted in lowering of the forebay, and consequently the power head, by 0.2 foot.

19. Although velocities were slightly higher than desirable, Bradford Island Excavation Plan 5 with Eagle Point Excavation Plan 3 provided an acceptable design from the standpoint of island width, head losses, and flow direction in the upstream lock approach. Therefore, data were obtained with additional flow conditions (including five combinations of discharge and pool elevation), and the resulting conditions were generally satisfactory with all flows. Velocities through the approach ranged from about 2 fps near the south shore to about 5-7 fps in the main channel. There was no difficulty encountered when handling the towboat in the upstream approach channel; however, handling the towboat in the downstream approach was much more difficult. When the Plan 2 downstream channel was installed (photograph 2), towboat navigation became considerably easier and safer. The Site D powerhouse and lock location appeared to be satisfactory when Bradford Island Excavation Plan 5, Eagle Point Excavation Plan 3, and the downstream approach Plan 2 were incorporated in the design.

20. After Site D tests had been completed, the results of a new survey of the powerhouse forebay of the Bonneville Dam were received. The survey indicated that the existing powerhouse channel has approximately 13.5 percent more capacity than the model channel at pool elevation 74. With Bradford Island excavation to elevation 40, the

difference in existing and modeled capacities is about 10 percent. Therefore, velocities and head losses for plans with Bradford Island excavation to elevation 40 would be slightly less than indicated by the previous tests. The flow conditions for plans with Bradford Island excavation to elevation 20 would not be significantly different from those indicated in the model.

Site E Powerhouse and Navigation Lock

21. The structures for Site E consisted of an eight-unit powerhouse adjacent to the south end of the existing ten-unit powerhouse (similar to Site D) and an 86- by 675-foot navigation lock located on the north shore upstream from the right end of the existing spillway. The Site E powerhouse and lock were not incorporated in the model; instead, the effects of the eight-unit Site E powerhouse were simulated by passing flows through the Site D powerhouse and navigation lock structures.

22. Initially, Bradford Island Excavation Plan 2 (plate 16) and Eagle Point Excavation Plan 2 (plate 18) were installed in the model (photograph 3). Tests were made with river discharges of 300,000, 460,000, and 600,000 cfs with (1) both powerhouses operating and (2) only the existing powerhouse operating. Velocities in the sheltered area between the guide walls at the upstream entrances were considered satisfactory; however, velocities in the navigation approach were high (10 fps at 600,000 cfs river discharge with 458,000 cfs spillway flow). The high velocities were directed obliquely across the navigation approach channel entrance (photograph 4) making it virtually impossible to negotiate a safe entrance into, and difficult to negotiate a safe exit out of, the approach channel. Velocities between Bradford Island and Eagle Point ranged from 7 to 16 fps depending on powerhouse operation. The water surface drop (approximate head loss) in the powerhouse channel exceeded 3.0 feet when both powerhouses were operated indicating that the powerhouse channel had too little capacity.

23. Tests were made to determine the minimum probable head loss at the powerhouse. With Bradford Island Excavation Plan 4 (plate 17) and Eagle Point Excavation Plan 1 (plate 18) and a riverflow of 600,000 cfs (spillway flow 282,000 cfs, both powerhouses operating) head losses were about 0.5 feet in the powerhouse channel.

24. Tests were made of several entrance plans designed to reduce velocities and improve conditions for navigation. Plan 2 moved the right bank of the upstream entrance inland and extended it upstream. The curved right bank of Plan 2 was straightened in Plan 3, and then Boat Rock and Picture Rock were removed to elevation 30 and 35, respectively. The left guide wall was made straight and extended to the elevation 25 contour for Plan 4. Each subsequent plan improved navigation conditions; however, testing with the remote-controlled towboat indicated that a wide entrance to the Plan E lock (entrance Plan 3 or 4) was required for safe entry of large tows into the lock with spillway flows up to approximately 317,000 cfs (460,000-cfs riverflow). The model indicated that entry into the lock at higher discharges would be possible but hazardous since precise and rapid maneuvering of the model towboat was required.

25. Preliminary tests were made to determine the effect of reduced Bradford Island excavation on losses in the powerhouse channel. The different excavation plans tested are shown on plate 21 and the results are listed in table C.

Site C Powerhouse and Navigation Lock

26. Site C structures originally tested included a ten-unit powerhouse on the north (Washington) shore and the Site D navigation lock with the upstream approach widened to approximately 300 feet. The proposed Site C development was to use the existing lock for the present but would include construction of a second, larger lock in the future. Therefore, the effect of Bradford Island excavation on

approach conditions to the existing and proposed locks was investigated. The Site D powerhouse previously tested was left in the model but isolated to prevent flow from entering this portion of the model. The upstream portion of the existing navigation lock was reinstalled in the model. The general layout is shown on plate 22 and photograph 5. Bradford Island Excavation Plan 8, which was similar to Plan 6-D (plate 21) except for bank sloping between the fish ladder exit and existing powerhouse, was initially modeled based on results of previous upstream approach tests accomplished for the Site E investigations.

27. Water surface elevations were observed with river discharges from 141,000 to 600,000 cfs with varied operating conditions. Losses in the Site C powerhouse channel varied from 0.1 feet at 220,000 cfs to 0.6 feet at 600,000-cfs riverflow with both Bradford Island Excavation Plan 8 and the existing Bradford Island configuration. Losses in the existing powerhouse channel varied from 0.3 feet at 141,000 cfs to 0.7 feet at 600,000 cfs with Bradford Island Excavation Plan 8 and 1.0 to 1.3 feet for similar discharges with the existing Bradford Island configuration.

28. Velocities and flow patterns were obtained in the upstream approaches to both powerhouses assuming that only the existing lock was operable under the following conditions: maximum flow (220,000 cfs) through the Site C powerhouse with 300,000-cfs river discharge and maximum flow (361,000 cfs) through both powerhouses with river discharges of 460,000 and 600,000 cfs. Maximum velocities in the Site C powerhouse approach varied from 6 to 10 fps with a river discharge of 300,000 to 600,000 cfs, respectively. Surface eddies occurred just upstream from both ends of the Site C powerhouse with each flow tested (photograph 6). A full-depth eddy occurred along the north side of the Site C powerhouse approach at 600,000 cfs. Maximum velocities in the existing powerhouse approach channel varied from about 4 to 8 fps with river discharge varying from 300,000 to 600,000 cfs.

29. Downstream flow conditions were observed with maximum flow through the Site C powerhouse (220,000 cfs) and river discharges of 300,000, 460,000, and 600,000 cfs. Flow tended to follow the right bank, and eddies formed along the left bank upstream from the spillway channel and between the spillway and powerhouse channels (photograph 7). Maximum velocities ranged from 7 to 9 fps along the right bank upstream from the spillway channel, from 7 to 10 fps in the excavated channel downstream to gage 4, and from 9 to 13 fps at the confluence of the natural river channel and the existing powerhouse channel. The head losses in the Site C powerhouse tailrace indicated that decreased excavation in the upstream portion of the channel might be possible without increasing overall losses. Losses in the existing powerhouse tailrace indicated that its capacity should be increased.

30. A study of navigation conditions in the lock approaches was made with the radio-controlled towboat. Conditions in the upstream entrance to the existing lock both with and without the Site C lock operable were signficantly improved with the Bradford Island Excavation Plan 8; crossflow at the entrance was reduced but would still influence large, slow-moving tows. The upstream approach channel to the Site C lock provided nearly ideal entrance and exit conditions for all flows. The towboat had no difficulty entering either lock from downstream at 300,000 cfs when the tow was maneuvered in line with the flow. At 600,000 cfs (photograph 8) the towboat was required to maneuver at full power to enter either lock; downstream movement required good alinement of tow and flow.

31. In order to evaluate the effect of Bradford Island excavation, the existing approach conditions were reproduced in the model by temporarily installing the wetted portion of the upstream end of Bradford Island (photograph 9). Water surface elevation data indicated that operation with the existing Bradford Island had no effect on losses in the approach channel to the Site C powerhouse for river discharges up to 460,000 cfs and caused only 0.1-foot variation at 600,000 cfs.

32. Tests were made with a variety of river discharges (ranging from 141,000 to 600,000 cfs with flow distributed to maintain maximum discharge through the existing powerhouse) to determine if navigation conditions were affected by flow to the Site C powerhouse. Entry of the model towboat into the existing upstream approach channel between Eagle Point and Bradford Island and maneuvering through the channel to the navigation lock was difficult at 300,000 cfs and nearly impossible at 600,000 cfs. Moving upstream past Eagle Point was not difficult at 300,000 cfs, but it was necessary to maneuver the tow close to Bradford Island on the north and Eagle Point on the south at 600,000 cfs in order to avoid the high river channel velocities and grounding on Boat Rock.

33. Three bank alinement revisions were tested in the Site C powerhouse tailrace. The revised alinements in the models were accomplished by adding crushed rock along the left bank. The resulting tailwater elevations with the original (Plan C-1) and revised (Plans C-2 through C-4) tailrace excavation are listed in table D. Revised alinements of the left bank eliminated the slack water areas and produced downstream flow along the full length of both banks (photograph 10). The realined channels caused slight changes of tailwater at the Site C powerhouse--0.1 to 0.2 feet with discharges of 220,000 to 460,000 cfs--indicating small increases of head on the power units could be obtained with the different plans.

34. A brief study of flow conditions in the Garrison Rapids reach opposite Ives Island (RM 142.8) was conducted to determine if velocities during a peaking operation would adversely affect commercial navigation. Maximum velocities ranging between 4 to 12 fps were measured during simulation of the peaking operation hydrograph. Prototype powerhouse tailwater levels were reproduced accurately, but the model did not reproduce the correct water surface slope in the river through the reach. The model results were therefore considered to be potentially misleading and tests were discontinued.

35. The model indicated that the Site C powerhouse provided a workable plan for both power operation and navigation. Based on economic considerations, Site C was subsequently selected as the powerhouse site, and detailed model tests were conducted to optimize the design of the powerhouse and appurtentant structures.

PART V: FINAL DESIGN

Site C-3 Powerhouse

36. The eight-unit Site C-3 powerhouse--a modification of the Site C powerhouse--was selected for construction. Although the Plan C lock was proposed for future construction, its design was not studied in this model. Plan C lock alinement and navigation channel improvements studied with the comprehensive model were reported in "Columbia River and Tributaries, Bonneville Lock and Dam, Oregon and Washington Feasibility Report, Hydraulic Model Studies" dated March 1978. The project layout is shown on plate 23 and photograph 11.

37. Project construction began soon after site selection. Model testing of the following design and/or as-built conditions continued:

a. Design alternatives to minimize upwelling in the tailrace channel.

b. Design alternatives for the upstream and downstream channels and observations of as-built forebay flow conditions.

c. Observation of the dispersion of turbid water from the newly excavated Site C downstream channel after removal of the cofferdam.

d. Observation of flow conditions during the flushing of newly excavated material from the tailrace.

e. Data accumulation for determining the best combination of flows from the two powerhouses to facilitate fish passage at the main fishway entrances and exits and to define flow conditions at the existing and proposed new navigation lock approaches.

f. Observation and design of the ice and trash chute.

The model studies for items "b" through "e" were made on the 1:100-scale comprehensive model. 1:40- and 1:80-scale models were used in the item "a" studies, and a 1:20-scale model was used for item "f".

Powerhouse Draft Tube

38. The 1:80- and 1:40-scale single powerhouse unit models were used to investigate interference with fishway attraction flow by upwelling from the outflow of the powerhouse unit adjacent to the fishway. Operating experience at John Day Dam had indicated that such conditions are detrimental to fish passage. The 1:80-scale model simulated the draft tube downstream from the elbow and was used to determine the effect various plans of draft tube and excavation runout slopes would have on upwelling downstream from the powerhouse. The 1:40-scale model simulated all features of the unit except for the wheel and was used to study the effects that various left wall design plans would have on outflow conditions. The effects of placing a deflector over the draft tube exit were also tested in the models. A unit discharge of 22,000 cfs was used with each model.

Draft Tube Invert Slope

39. The 1:80-scale model was tested with the low point of the model at elevation -79.7. Twenty-six different geometric configurations were tested. The design of the draft tube downstream of the elbow was varied from that with a horizontal runout to that with a 1 vertical (V) on 3.5 horizontal (H) slope. The tailrace between the draft tube exit and the channel was excavated to elevation -20 with the excavation varied to include no bench, and 50- and 100-foot-long benches. Runout slopes of 1V:4H, 1V:5H, and 1V:6H were tested, and tailwater was varied between elevations 10 and 55. A representative model is shown in photograph 12.

40. Changes in the runout slope and tailrace bench had very little effect on the location and severity of the boil. Changing the draft tube slope from 1V:3.5H made little difference in the boil

location. The 1V:10H invert slope produced a moderate downstream shift and reduced the upwelling to a rolling action. The horizontal invert moved the upwelling further downstream and created only very mild rolling action with considerable quiet water between rolls. Increasing the tailwater above elevation 10 also caused the upwelling to move downstream and change from a localized boil to a large subdued boil for all plans tested. Plates 24 through 27 illustrate the effects of the geometric changes on the boil conditions.

41. A 15-foot-wide deflector the full width of the unit was installed at the top of the draft tube exit in another attempt to move the boil downstream and farther from the proposed fishway entrance on the left wall. The deflector caused the boil to surface 10 to 20 feet farther downstream and to expand over a wider section of the flume.

42. A 15-foot-wide ledge extending 120 feet downstream from the powerhouse was installed along the left wall to isolate the fishway entrance from the powerhouse boil. When the ledge was built to elevation 3, flow conditions above the ledge were only fair for fish passage due to the waves and rough water caused by boil expansion along the ledge. Lower ledge elevations produced boiling over the top of the ledge at tailwater elevation 25. Higher ledge elevations produced insufficient water cover over the ledge at tailwater elevation 10.

Left Wall Design Plans

43. Initial data for the 1:40-scale model tests were obtained with parallel sides in the flume and a runout slope of 1V:4H. The boil downstream from the powerhouse was concentrated along the left wall as a result of angular flow out of the scroll case and draft tube. This was in agreement with the 1:80-scale model and with prototype observations at several existing powerhouses.

44. In the original-design plan, the left wall of the flume was reconstructed to duplicate the south end of the proposed Site C-3 second powerhouse. The left wall of the model was recessed downstream from the powerhouse and included the two entrances to the fishway system and the wall of the trash chute downstream from the entrances (photograph 13). Location of the boil with tailwater elevations 16 and 25 was observed with the original plan as well as with the following variations:

a. A different invert slope at the wall.

b. An angled wall at the downstream fishway entrance.

c. A deflector over the draft tube exit.

d. A ledge along the wall.

e. A short section of straight wall downstream from the powerhouse.

f. An extension of the wall at the downstream fishway entrance.

g. Two lengths of raised invert at the downstream entrance.

h. A combination of the draft tube deflector and the short section of straight wall at the powerhouse.

45. The results of tests with the various geometries indicated that four plans had good flow conditions or could be improved to have good flow conditions by adding an angled wall at the downstream fishway entrance. These four plans are as follows:

a. An angled wall at the downstream fishway entrance and the alternative invert along the left wall (photograph 14);

b. The downstream fishway entrance moved 58.9 feet downstream and the alternative invert along the left wall (photograph 15 with angled wall at the downstream fishway entrance);

c. A short section of straight wall downstream from the powerhouse with a deflector over the draft tube exit depressed 15 degrees (photograph 16 with angled wall at downstream fishway entrance); and

d. A short section of straight wall downstream from the powerhouse with the alternative invert along the left wall and a deflector over the draft tube exit depressed 15 degrees (photograph 17 with angled wall at downstream fishway entrance).

Two other plans were considered to produce fair-to-good conditions, while all other plans were considered poor due to excessive upwelling, upstream flow, or extremely rough water near the fishway entrance. The results of the preliminary study and the four good plans are summarized in table E.

Tailrace Channel

46. Details of the powerhouse and accompanying channels are shown on plate 23. Flow patterns and velocities in the original-design tailrace channel (Plan C-6A) are shown on plates 28 and 29 with river discharges of 168,400, 220,000, 360,000, and 510,000 cfs. The original-design tailrace channel produced poor flow conditions at the downstream fishway entrance on the north end of the powerhouse; fishway flow was either drawn into the boil at the powerhouse or caught in a large eddy along the north bank. Flow from the south fishway was satisfactory with all flows. Flow in the tailrace channel was generally satisfactory; however, small areas of slack water or small eddies occurred along the left bank of the channel (photograph 18). Maximum velocities of 6 fps occurred near the right bank but were generally far enough offshore to not be a problem for

migrating fish. Flow conditions at the confluence of the tailrace channel with the spillway and existing powerhouse channel were satisfactory with the exception that a small eddy existed on the downstream end of Bradford Island.

47. Four modifications to the original Plan C-6A tailrace runout were studied to determine the effects on flow conditions at the north fishway entrance. The plans tested were as follows:

a. Constant runout slope of 1V:3.38H to elevation -20.

b. Training wall between units 17 and 18 at elevation -25.

c. Training wall between units 17 and 18 at elevation -38.

d. Training wall between units 17 and 18 at elevation -25 with a constant runout slope to elevation -20.

Flow patterns with the original plan and the modifications were observed with river discharges of 168,400, 360,000, and 510,000 cfs. Flow conditions existing with a discharge of 360,000 cfs for each plan are shown on plates 30 through 34. The tests indicated that flow conditions at the fishway entrance were improved by the training wall (photographs 19 through 22).

48. In an attempt to improve attraction conditions for migrating fish, tailrace channel Plan C-6B was devised and tested. This plan decreased the excavation of the original design Plan C-6A (plate 23) by leaving the downstream end of Bradford Island in its existing condition. With a powerhouse discharge of 160,000 cfs, this plan produced a higher tailwater at the powerhouse and resulted in a loss in power head of 0.6 feet and 1.3 feet with river discharges of 309,400 and 208,400 cfs, respectively. Most of the eddies that occurred along the left bank with the original design were still present (photograph 23).

49. The Plan C-6C tailrace channel raised the excavated invert 10 feet to elevation -10. Velocities increased slightly, and head loss on the powerhouse increased to 1.7 feet with a 208,400-cfs river discharge (160,000 cfs through the Site C powerhouse). Slack water areas still existed along the banks (photograph 24). The Plan C-6D tailrace channel design realined the banks (photograph 25) to produce downstream flow along them.

50. The loss of power (due to an increase in tailwater) created by reducing the invert elevation to elevation -10 (Plans C-6C and C-6D) was too great to justify, but the realined banks of Plan C-6D produced good fish attraction flow and satisfactory bank velocities. The Plan C-6E (proposed final design) tailrace channel incorporated the realined banks of Plan C-6D and an invert excavated to elevation -20.

51. The Plan C-6E tailrace channel was tested to determine bank velocities and fish attraction conditions. Velocities along the right bank 2,500 feet downstream from the powerhouse were measured with river discharges of 168,400, 208,400, and 309,400 cfs (160,000 cfs through the Site C-3 powerhouse for all flows). The maximum velocities 4 feet from the bank were 4.9, 4.1, and 3.7 fps.

52. Flow conditions and velocities were observed downstream from each of the fishway entrances in the Site C-3 powerhouse with the Plan C-6E tailrace and river discharges ranging from 80,000 to 510,000 cfs with varied Site C-3 powerhouse discharge. Velocities and surface flow with partial operation of the powerhouse and river discharges of 80,000 and 148,000 cfs are shown on plate 35 and photograph 26. Velocities and surface flow with river discharges of 168,400 through 360,000 cfs and full powerhouse operation are shown on plates 36 through 38 and photographs 27 through 29. Conditions with a river discharge of 510,000 cfs are shown on plate 39. Flow conditions in the tailrace channel were satisfactory with all the discharges.

53. An investigation was made of the effects on backwater (at the dam structures) resulting from restricting the flood plain with fill at Hamilton Island and the proposed relocated town site of North Bonneville, Washington. The data collected include flow conditions and water surface elevations both upstream and downstream of the structures. The existing and proposed topographies of Hamilton Island and the adjoining area are shown on plates 40 and 41, respectively.

54. The following flow conditions were studied:

Discharge, cfs				Water Elevation, feet	
River Discharge	Existing Powerhouse	Plan C Powerhouse	Spillway*	Pool (Gage R)	Tailwater (Gage 9)
700,000	142,000	160,000	398,000(G)	74.0	35.6
700,000	Closed	Closed	700,000(G)	74.0	35.6
850,000	143,000	160,000	547,000(G)	75.5	39.9
850,000	Closed	Closed	850,000(G)	75.5	39.9
1,000,000	143,000	160,000	697,000(G)	75.5	43.7
1,000,000	Closed	Closed	1,000,000(G)	75.5	43.7
1,200,000	143,000	160,000	897,000(G)	75.5	48.3
1,200,000	Closed	Closed	1,200,000(G)	75.5	48.3
1,420,000	143,000	160,000	1,117,000(G)	75.5	52.6
1,420,000	Closed	Closed	1,420,000(U)	—	52.6
1,700,000	Closed	Closed	1,700,000(U)	—	—
2,100,000	Closed	Closed	2,100,000(U)	—	64.0

* (G) and (U) refer to gated and ungated spillway operation, respectively. With the two highest discharges tested, a portion of the water overtopped Bradford Island as well as the lock and powerhouse structures.

All powerhouse units were operated at full capacity when in use. A fish attraction flow of 2,400 cfs was passed through the exterior spillway bays at river discharges of 700,000 and 850,000 cfs. Spillway flow with river discharges of 1,000,000 through 1,420,000 cfs was not passed uniformly through all spillway bays.

55. The fill increased tailwater at the Plan C powerhouse (Gage T3) by 1.7 and 2.2 feet with a discharge of 1,420,000 cfs (spillway and both powerhouses operating) and 2,100,000 cfs (spillway flow only), respectively. With the same discharges, the increases were 1.6 and 2.7 feet at the existing powerhouse (Gage TW) and 1.3 and 1.6 feet at the spillway (Gage T1). Backwater effects from the fill were apparent in the pool with only the two highest river discharges (1,700,000 and 2,100,000 cfs). The maximum increase in pool level was 1 foot at the spillway (Gage R) with 2,100,000 cfs. Bradford Island and the two navigation locks were overtopped during the two highest discharges both with or without the fill. The island between the spillway and the Plan C powerhouse was also overtopped with the higher discharge.

56. A small portion of the new town site of North Bonneville was inundated during a river discharge of 1,000,000 cfs. The inundation of the town increased to approximately elevation 65 (25 feet deep) with a river discharge of 2,100,000 cfs.

Approach Channel

57. The original-design (Plan C-1) approach channel is shown on plate 23 and photograph 11. Flow patterns and velocities in the approach channel with river discharges of 168,400, 220,000, 360,000, and 510,000 cfs (160,000-cfs Site C-3 powerhouse discharge) are shown on plates 42 and 43. Conditions in the forebay channel were satisfactory with all flows except 510,000 cfs when downstream flow separated from the right bank and a large eddy formed along the bank from the powerhouse to beyond the fishway exit (photograph 30). Flow at the fishway exit was in the upstream direction. With lower discharges, good downstream flow occurred at the fishway exit.

58. Approach conditions and flow distribution were improved when the left bank upstream from the powerhouse was curved (approach Plan C-2) as shown on plate 44. Velocities along the slope of the

left bank ranged from less than 1 fps at 360,000 cfs to 5 fps at a 1,420,000-cfs river discharge (160,000-cfs Site C-3 powerhouse discharge). The flow impact on the face of the powerhouse was shifted to the right, and transverse flow at the powerhouse was reduced. Velocities along the face of the powerhouse upstream from each unit are listed in table F. Surface swirls that had been observed traveling the full length of the powerhouse with the Plan C-1 approach were reduced to an occasional swirl at either end. Bottom velocities at the top of the approach slope ranged from 5 to 13 fps with flows of 360,000, 510,000, 700,000, 850,000, and 1,400,000 cfs. Flow conditions for 360,000- and 1,420,000-cfs river discharges are shown on plate 44.

59. An alternative excavation plan (approach Plan C-3) which included a constant 1V:5H approach slope to the powerhouse was also tested. Flow conditions with Plan C-3 are shown on plate 45. Velocities along the left bank increased slightly for the observed flows. Velocities along the upstream face of the powerhouse are listed in table G.

60. The Plan C-4 approach channel represented the contractor's proposed excavation and allowed a larger work area. General flow conditions in the approach channel (plate 46) were the same as those with Plans C-2 and C-3. Velocities along the left bank ranged from 2 fps at 360,000 cfs to 6 fps at 1,420,000 cfs; at the top of the approach slope, the maximum bottom velocity was 11 fps. A maximum bottom velocity of 14 fps was observed on the toe of the left bank indicating the need for riprap protection. Velocities along the upstream face of the powerhouse are listed in table H. Flow patterns near the fishway exit on the right bank were good at discharges up to 440,000 cfs; at larger discharges the eddy at the north end of the powerhouse became large enough to create upstream flow at the exit.

61. Additional refinements were developed for the left bank of the approach channel. The top of the original curved nose on the island between the powerhouse and spillway was lowered 10 feet to elevation 80 and then shortened by distances of 50, 75, and 100 feet. Flow conditions with each plan were observed for discharges of 360,000 and 1,420,000 cfs. The plan with the nose 50 feet shorter produced the best flow conditions in the forebay and at the fishway exit and was selected as the final design approach channel.

62. Tests were made with the final-design approach channel using the proposed schedule for bringing each new unit on line with the minimum and maximum river discharges that might occur at that time of year (tables I and J). Project operation flow conditions prior to activating the second powerhouse (plate 47) and with only unit 18 on line (plate 48) produced flow conditions along the Washington shore that were poor for upstream fish migration. Flow along the shore between the powerhouse and the fishway exit was in the upstream direction and did not provide conditions conducive to fish guidance. Flow conditions improved when unit 17 was brought on line (plate 49) and slow downstream flow occurred near the fishway exit. Conditions improved further with the addition of unit 16. As the remaining units were added, flow conditions continued to improve until downstream velocities along the Washington shore reached a maximum of 4 fps. A maximum riverflow of 313,000 cfs was observed with six of the eight units operating. Flow conditions with all eight units available but only six (147,000 cfs river discharge) units operating or two (69,000 cfs river discharge) units operating are shown on plate 50. The model indicated that the proposed operating schedule provided flow conditions in the forebay that were adequate for upstream fish migration.

63. During project construction it became apparent that the as-built upstream nose of Cascade Island had considerably more native material left in place than anticipated in the plans previously model tested. Flow conditions (plate 51) were observed in the as-built

forebay with river discharges of 360,000 and 420,000 cfs (160,000-cfs powerhouse flow) to determine if the change in bank configuration had any adverse effect on either flow to the powerhouse or fish passage conditions. With a discharge of 360,000 cfs, fish migration conditions on the right bank were unchanged from that of the design condition. The point of flow division on the face of the powerhouse was shifted slightly but this caused no eddies or flow disturbances. Velocities over the point of Cascade Island were no greater than 4 fps. The 420,000-cfs discharge flow conditions were approximately the same as those which occurred with 360,000 cfs--good downstream flow occurring near the fishway exit and flow into the face of the powerhouse remaining relatively unchanged. Division of flow on the nose of the island was nearer the center with maximum velocities of 4 or 5 fps. A brief test of 850,000 cfs showed the flow to split exactly on the center of the nose with velocities of 10 or 11 fps. The tests with the as-built forebay showed that only minor changes in local flow conditions resulted from the departure from previously proposed and tested forebay configurations. Flow to the powerhouse at the nose of Cascade Island and at the fishway exit was satisfactory.

Turbidity Studies

64. Turbidity tests made to simulate loose material movement in the newly excavated Site C downstream channel were conducted in two phases. In Phase 1, observations were made to simulate the dispersion of turbid water in the downstream channel after removal of the cofferdam. In Phase 2, velocities and flow directions in the channel were observed to simulate the effect of individual power units being activated. These hydraulic conditions will affect the flushing of fine material from the excavated channel into the river.

Phase 1

65. For the tests, a heavy concentration of dye was placed in the excavated channel and a plywood bulkhead was placed across the downstream end. The bulkhead was removed and water samples were taken at four points at each of the four ranges downstream (plate 52) at selected time intervals. Turbidity was measured as percent concentration of the original concentration of dye in the excavated channel.

66. Two operating conditions were individually tested four times. The first condition involved a 240,000-cfs river discharge with 141,000 cfs through the existing powerhouse and 99,000 cfs over the spillway. The dye was slowly pulled out of the excavated channel by flow moving past the downstream end of Cascade Island (between the Site C-3 powerhouse and the spillway). Maximum concentration at all ranges occurred after about 3 hours of model operation and averaged 5.7 percent. At the end of 18 hours, the concentration in the excavated channel was still quite strong in the upper end of the excavated channel and 1 to 2 percent moved past the tip of Cascade Island.

67. The second condition tested had the same powerhouse and spillway flow as the first condition but also included 3,400 cfs through the Site C-3 powerhouse fishway system--1,000 cfs through the collection system and 1,200 cfs through both the north and south fishway entrances (243,400-cfs river discharge). Maximum concentration at all ranges occurred after about 3 hours of operation and averaged 13.6 percent. The channel was flushed clean after 18 hours.

Phase 2

68. Observation of velocities and flow direction were made with four river discharges ranging from 186,800 to 264,400 cfs. The existing powerhouse was operated at full capacity. With the two

lower riverflows, 2,400 cfs was spilled through spillway bays 1 and 18 as fish attraction flow. With the two higher flows, 100,000 cfs was spilled uniformly through all 18 spillway bays.

69. With the two lower flows (186,800 and 206,800 cfs), two and three units of the Site C-3 powerhouse were operated and partial flow was released from the fish facilities. Flow in the new channel reached velocities of 4 to 6 fps along the channel invert near the Site C-3 powerhouse, 3 fps or less downstream from the junction with the spillway channel, and as high as 6 fps downstream from the existing powerhouse channel. In the Site C downstream channel, flow was strongest along the right side with upstream flow and eddies along the left side.

70. With the two higher discharges (249,400 and 264,400 cfs), a single Site C-3 powerhouse unit (No. 18) at the north end of the structure was operated along with the fish facilities. The powerhouse unit was operated with 5,000 and 20,000 cfs (249,400- and 264,400-cfs river discharges, respectively). Invert velocities in the upstream half of the Site C downstream channel were less than 1 fps with the low unit discharge and from 2 to 4 fps with the high unit discharge. Flow along the left bank was slack or drifted upstream. Invert velocities immediately downstream of the spillway channel were 4 to 5 fps. Invert velocities immediately downstream of the existing powerhouse channel were 4 to 7 fps. The higher velocities continued past Hamilton Island.

Project Operation For Fish Passage Studies

71. Power unit scheduling tests were conducted to provide data for determining the best combination of flows from the two powerhouses to facilitate fish passage at the main fishway entrances and exits and to define flow conditions at the existing and proposed navigation lock approaches. The operating conditions studied were those expected to occur during the interim period when the second

powerhouse would be brought up to full operation and the project completed. Tests were conducted at six river discharges (80,000, 100,000, 180,000, 312,000, 350,000, and 510,000 cfs) representing the full range of flows for adult fish passage.

80,000-cfs River Discharge

72. With a river discharge of 80,000 cfs and only unit 18 operating in the second powerhouse (north shore unit first on line), flow directions and velocities were good for fish passage along the north bank of the tailrace, at the north fishway entrance, and at the juvenile bypass outlet downstream from units 16 and 17. A large, slow eddy (velocity less than 1 fps) formed in the tailrace at the south end of the powerhouse. The 10-fps outflow from the south fishway entrance was quickly dissipated in the slow eddy. All fish attraction in the tailrace was at the north shore fishway entrance. When only unit 17 was operating, flow along the north bank was downstream but very slow near the fishway entrances. The main attraction flow was along the toe of the north bank to the boil of unit 17. Flow at the south bank was identical to conditions with only unit 18 operating. With only unit 16 operating, flow along the north bank was upstream and fish attraction was poor at all main entrances. With units 16, 17, and 18 operating simultaneously, flow conditions were excellent at the north fishway entrance. Fish attraction to the south entrance was nearly nonexistent.

73. With units 1, 2, and 10 operating in the existing powerhouse, good downstream flow occurred along both banks of the tailrace and past the juvenile outfall structure downstream from unit 10. Little change in the flow pattern occurred if unit 9 was operated instead of unit 2.

74. Flow conditions throughout the tailrace, in the forebays, and at the navigation lock approaches with units 1, 2, and 10 (existing powerhouse) and 16, 17, and 18 (second powerhouse) operating are

shown on plate 53. At the Bradford Island (upstream) exit, a very slow eddy occurred that would attract fish toward the powerhouse, then into the middle of the forebay, and finally upstream into the reservoir. Flow conditions were good at all lock approaches.

100,000-cfs River Discharge

75. With a riverflow of 100,000 cfs and a good balance of flow between the powerhouses, four units of the new powerhouse could be operated. When units 11, 16, 17, and 18 of the second powerhouse were operated, flow along the north bank and by the outfall structure was good for fish passage but flow along the south bank was upstream (plate 54). At a distance of 75 to 100 feet out from the toe of the south bank, flow was downstream with velocities 2 to 3 fps and offered good attraction directly to the downstream south fishway entrance. Flow from units 1, 2, and 10 of the existing powerhouse provided good fish passage conditions along both banks of the tailrace. Velocities and flow directions at the lock approaches were good.

180,000-cfs River Discharge

76. With units 11 through 13 and 16 through 18 of the second powerhouse and units 1 through 4 and 7 through 10 of the existing powerhouse in operation with a river discharge of 180,000 cfs, general flow conditions were as shown on plate 55. Flows along both banks of both tailraces were good both for attraction to all the main fishway entrances for juvenile release at the outfalls. Attraction flows at both fishway exits were better than those occurring with lower discharges. Flow at both upstream lock approaches was good, but flow at the downstream approaches was 5 to 6 fps in the reaches where towboats turn across the flow to enter or exit the approach channel.

312,000-cfs River Discharge

77. With a river discharge of 312,000 cfs all 18 powerhouse units could be operated with minimal spill for fish attraction in the spillway channel. General flow conditions are shown on plate 56. Flows along the south bank of the second powerhouse tailrace and both banks of the existing tailrace were good for fish attraction; flow along the north bank of the second powerhouse tailrace was acceptable but not as strong as with 100,000- and 180,000-cfs river discharges. Attraction flows at the fishway exits were better than with lower discharges. Good flow conditions occurred at both juvenile outfalls. Flow conditions at the upstream approach to the existing lock were acceptable; however velocities of 4 to 6 fps existed at the upstream approach to the proposed new lock and would make exiting difficult. Velocities in the turn areas to the downstream lock approaches were 5 to 8 fps, and towboats would have to maneuver carefully in these areas. Flow at the downstream lock approaches with discharge from the second powerhouse was generally the same as that occurring under the old project operating condition when the spillway was operating.

350,000-cfs River Discharge

78. General flow conditions with a river discharge of 350,000 cfs, all 18 powerhouse units operating, and 47,500 cfs being spilled are shown on plate 57. Fish attraction flows and juvenile release flows in both tailraces were satisfactory. Flow conditions were good at both fishway exits. Velocities were higher than desired at all lock approaches.

510,000-cfs River Discharge

79. General flow conditions with a river discharge of 510,000 cfs, all 18 units operating, and 225,000 cfs being spilled are shown on plate 58. Flows for fish attraction and juvenile release were

satisfactory. High velocities at the downstream end of Bradford Island and along the south bank downstream from the project would hinder fish passage to the tailrace. Flow conditions were good at the Bradford Island fishway exit but were unsatisfactory at the north shore exit. Velocities were higher than desired at all lock approaches.

Ice and Trash Chute

80. The second powerhouse ice and trash chute, which includes the emergency fishwater supply intake, was reproduced in a 1:20-scale model. Initially the model included the original-design proposal but the fishwater intake was omitted (photograph 31). Later the chute was modeled with a revised headwall, and the fishwater intake was included (photograph 32). Details of the initial and modified chute models and the emergency fishwater supply intake are shown on plates 59, 60, and 61, respectively.

81. Observations in the initial model were made with a discharge of 2,200 cfs and each of the following three inflow conditions proposed for use during fishwater withdrawal:

a. Control gate set for undershot flow with a sloped floor immediately downstream from the gate.

b. Undershot inflow with a stepped floor at the gate.

c. Overshot inflow with a stepped floor.

With all three conditions, the toe of the hydraulic jump was in the curved section of the chute and the jump was fully formed approximately 50 feet upstream from the fishwater intake (photograph 33). Spray and occasional waves along the walls wet the roof between the jump and the fishwater intake. Freeboard in the chute was a minimum of 1 to 2 feet. Water surface profiles in the chute (plate 62) show

that the hydraulic jump would not interfere with withdrawal of water for the fishways. Velocity distribution across the chute was uniform at the fishwater intake with all conditions (plate 63).

82. The passage of trash was observed with the original headwall plan, and 500 cfs overshot inflow. Simulated logs as long as 60 feet passed through the chute satisfactorily. Occasionally a 60-foot-long log hit the lower edge of the headwall.

83. The revised model was tested with an inflow of 2,200 cfs without stoplogs on the intake control weirs and with stoplogs to elevation 46.5 at the downstream end of the chute. The water surface in the chute was at elevation 48.5. Approximately 2,000 cfs was discharged through the fishwater intake, and 200 cfs spilled from the chute. When the stoplogs at the downstream end of the chute were raised to elevation 49.5, the water surface rose to elevation 49.0 and the entire 2,200 cfs passed through the fishwater intake. Flow through the fishwater intake was satisfactory with both conditions.

84. With an overshot inflow of 2,200 cfs and fishwater withdrawal of 2,000 cfs, logs that entered the chute did not hit the revised headwall. The logs were swept along on the water surface to just beyond the fishwater intake where they were held in place by the low-velocity upstream surface flow. Long logs passed to that point satisfactorily; short logs were occasionally bounced against the roof by waves. No logs accumulated along the curtain wall at the fishwater intake.

PART VI: SUMMARY

85. The Bonneville second powerhouse project was proposed to increase the power-generating capacity of the Bonneville Dam project. A 1:100-scale comprehensive model was employed to investigate proposed powerhouse sites, to aid in the design of the powerhouse channels, and to conduct project operation studies. Powerhouse outflow conditions were investigated with 1:80- and 1:40-scale models of a single powerhouse unit. A 1:20-scale model of the ice and trash chute was employed to assist in design of the chute and to investigate flow conditions at the emergency fishwater intake.

86. Three separate powerhouse and navigation lock concepts were tested--Sites D and E located on the south shore and Site C (final design location) on the north shore. The Site D concept included a six-unit powerhouse adjacent to the existing powerhouse with the navigation lock immediately left (south) of the Site D powerhouse. The Site E concept consisted of an eight-unit powerhouse adjacent to the existing powerhouse with the navigation lock on the north shore of the river to the right of the spillway.

87. Model tests indicated that with some design modifications all three concepts were hydraulically acceptable. In order to provide acceptable flow conditions in the approaches to the powerhouses and/or navigation locks, excavation of Bradford Island was required with all plans. The eight-unit Site C plan provided greater net benefits than any other site within the operating limits which were set for environmental reasons, and it was ultimately selected for final design.

88. The Site C concept included the second powerhouse located on the north (Washington) shore to the right of the spillway with the proposed future navigation lock (not included in these model

studies) located along the south shore. Several modifications to the Site C concept were made in the model leading to development of the final design Site C-3 plan.

89. Various acceptable design alternatives were developed for the draft tube exit area and left wall downstream from the powerhouse to improve flow conditions near the fishway entrances located in the left wall. A training wall was added in the tailrace runout between units 17 and 18 to improve flow conditions near the north shore fishway entrance. The original design banks of the tailrace channel were realigned to produce good fish attraction flow and satisfactory velocities along the banks. The tests indicated that raising the tailrace channel invert above elevation -20 could not be justified because the resulting loss of power (due to the increase in tailwater at the powerhouse) was too great.

90. Tests led to a modification (curving) of the original design left bank of the approach channel. The curved design reduced transverse flow and virtually eliminated surface swirls along the upstream face of the powerhouse that had been observed in the original design.

91. An ice and trash chute is located along the left side of the second powerhouse. An emergency fishwater supply intake is incorporated into the wall of the chute. Tests revealed that operation of the chute and location of the fishwater supply intake were acceptable. With all operating conditions tested, the hydraulic jump occurred upstream of the fishwater supply intake and a laterally uniform velocity distribution existed at the intake. Logs passed down the chute satisfactorily and did not accumulate near the fishwater supply intake.

TABLE A

WATER-SURFACE ELEVATIONS AT RIVER GAGES

Site D Powerhouse and Navigation Lock
Existing and Plan D Powerhouses Operating

Forebay Excavation Plans: Bradford Island	Eagle Point	Navigation Channel	Boat Rock and Picture Rock	500,000: 1	2	L	F-2	R	600,000: 1	2	L	F-2	R
				River Discharge in CFS / River Gage									
Water-Surface Elevation in Feet - Normal Pool Elev 74.0													
2	1	Original	Original	74.0	[illegible]	72.6	[illegible]	74.0	-	-	-	-	-
2	2			74.0	71.9	71.8	71.4	74.0	-	-	-	-	-
3	Original			74.0	73.7	73.6	73.5	74.0	74.0	73.2	73.4	73.1	74.0
3	2			74.0	73.6	73.6	73.5	74.0	74.0	73.5	73.6	73.3	74.0
3	1			74.0	73.7	73.6	73.3	74.0	74.0	73.6	73.7	73.4	74.0
4	Original			73.9	73.7	73.8	73.5	74.0	73.9	73.3	73.7	73.5	74.0
4	1			73.9	73.8	73.8	73.5	74.0	73.9	73.2	73.9	73.5	74.0
5	3			74.0	73.6	73.7	73.5	74.0	74.0	73.5	73.9	73.6	74.0
5	3	1		74.0	73.8	73.8	73.5	74.0	74.0	73.6	73.9	73.6	74.0
5	3	4		74.0	73.7	73.8	73.5	74.0	74.0	73.6	73.9	73.7	[illegible]
5	Original	Original	Original	-	-	-	-	-	73.9	73.3	73.9	73.6	74.0
5	Original	2	Removed	73.9	73.7	73.8	73.5	74.0	73.7	73.2	73.7	73.4	74.0
Water-Surface Elevation in Feet - Minimum Pool Elev 70.0													
5	3	1	Original	69.9	[illegible]	69.7	[illegible]	70.0	-	-	-	-	-
Water-Surface Elevation in Feet - Maximum Pool Elev 82.5													
5	3	1	Original	82.4	82.3	82.4	82.2	82.5	82.4	82.1	82.4	82.2	[illegible]

NOTES: 1. Plans shown on plates 16 through 19.
2. Gage locations shown on plate 15.
3. Pool elevation set at spillway gage R.

TABLE B

POWERHOUSE CHANNEL HEAD LOSS
RIVER GAGE 1 TO GAGES L AND F-2

Site D Powerhouse and navigation Lock
Existing and Plan D Powerhouses Operating

Forebay Excavation Plans				[illegible]			
				300,000		600,000	
				Head Loss in Feet Between River Gages*			
Bradford Island	Eagle Point	Navigation Channel	Boat Rock and Picture Rock	1 and L	1 and F-2	1 and L	1 and F-2
				Normal Pool Elev 74.0			
2	1	Original	Original	1.4	1.7	-	-
2	2			[illegible]	2.4	-	-
3	Original			0.5	0.7	1.1	1.3
3	2			[illegible]	0.7	[illegible]	[illegible]
3	1			[illegible]	.7	[illegible]	1.0
4	Original			0.2	0.4	[illegible]	0.8
4	1			0.2	0.4	[illegible]	0.7
5	3			0.3	0.5	[illegible]	0.8
5	3	1		0.3	0.5	[illegible]	0.8
5	3	4		0.3	0.5	[illegible]	0.8
5	Original	Original	Original	-	-	[illegible]	0.7
5	Original	[illegible]	Removed	0.2	0.4	[illegible]	0.7
				Minimum Pool Elev 70.0			
5	3	1	Original	0.3	0.5	-	-
				Maximum Pool Elev [illegible]			
5	3	1	Original	0	[illegible]	[illegible]	0.6

* Difference in EGL

NOTES: 1. Plans shown on plates 16 through 19.
2. Gage locations shown on plate 15.
3. Pool elevation set at spillway gage R.

TABLE B

TABLE C

WATER-SURFACE ELEVATIONS

Site E Powerhouse and Navigation Lock
Plan 3 Upstream Lock Entrance
Existing and Simulated Plan E Powerhouses Operating

Gage	Bradford Island Plan 5 Excavation (Elev 20) Eagle Point - Existing Boat and Picture Rocks - Existing	Bradford Island Plan 6A Excavation (Elev 20) Eagle Point - Existing Boat and Picture Rocks - Removed	Bradford Island Plan 6B Excavation (Elev 20) Eagle Point - Existing Boat and Picture Rocks - Removed	Bradford Island Plan 6B Excavation (Elev 20) Eagle Point Plan 2 Boat and Picture Rocks - Removed	Bradford Island Plan 6C Excavation (Elev 20) Eagle Point - Existing Boat Rock removed, Picture Rock in place	Bradford Island Plan 6D Excavation (Elev 30) Eagle Point - Existing Boat Rock removed, Picture Rock in place	Bradford Island Plan 6E Excavation (Elev 40) Eagle Point - Existing Boat Rock removed, Picture Rock in place
	River Discharge 300,000 CFS						
	Water-Surface Elevations						
1	74.0	74.0	74.0	74.0	74.0	74.0	74.0
2	73.7	73.5	73.6	73.6	73.5	73.4	73.2
R	74.0	74.0	74.0	74.0	74.0	74.0	74.0
L	73.8	73.7	73.7	73.7	73.7	73.2	72.9
F2	73.7	73.5	73.5	73.5	73.4	73.0	72.5
Between Gages	Approximate *Head Loss in Feet						
1-L	0.3	0.4	0.4	0.4	0.4	0.9	1.2
1-F2	0.3	0.5	0.5	0.5	0.6	1.0	1.5
Gage	**River Discharge 600,000 CFS**						
	Water-Surface Elevations						
1	73.8	73.8	73.8	73.8	73.7	73.7	73.7
2	73.2	73.1	73.1	73.4	73.0	72.9	72.8
R	74.0	74.0	74.0	74.0	74.0	74.0	74.0
L	73.7	73.6	73.6	73.8	73.5	73.0	72.6
F2	73.6	73.3	73.3	73.[illegible]	73.1	72.7	72.2
Between Gages	Approximate *Head Loss in Feet						
1-L	0.6	0.7	0.7	0.5	0.7	1.2	1.6
1-F2	0.6	0.9	0.9	0.7	1.0	1.4	1.9

* Difference in EGL

NOTES:
1. Bradford Island plan 5 excavation shown on plate 17.
2. Bradford Island plans 6A to 6E excavations shown on plate 21.
3. Eagle Point plans shown on plate 18.
4. Boat and Picture Rocks shown on plates 2 and 18.
5. Pool elevation set at spillway gage R.
6. Gage locations shown on plate 15.

TABLE D

EFFECT OF TAILRACE EXCAVATION ON WATER-SURFACE ELEVATIONS

Site C Structures
Pool Elevation 74.0

Gage*	Plan C-1 Tailrace			Plan C-2 Tailrace			Plan C-3 Tailrace	Plan C-4 Tailrace		
	River Discharge in CFS; Pool Elev 74.0									
	220,000	300,000	460,000	220,000	300,000	460,000	460,000	220,000	300,000	460,000
N	19.2	24.0	31.8	19.2	24.0	31.7	-	19.1	23.9	31.7
TW(S)	19.2	24.1	31.9	18.9	24.1	31.8	-	19.1	24.0	31.8
TW(N)	19.2	24.1	32.1	19.1	24.2	32.0	-	19.1	24.1	32.0
TS	19.5	24.2	32.8	-	-	-	-	19.5	24.2	32.8
T-1	19.6	24.3	32.8	19.4	24.2	32.9	32.8	19.5	24.3	32.8
T-2	19.6	24.4	32.8	19.6	24.4	32.9	32.8	19.4	24.4	32.7
T-3A	19.4	24.3	32.7	19.6	24.3	32.8	-	19.3	24.3	32.6
B	19.5	24.3	32.7	19.6	24.4	32.8	32.7	19.3	24.3	32.6
C	19.3	24.2	32.6	19.5	24.3	32.7	-	19.3	24.2	32.6
D	19.3	23.8	32.4	19.5	23.9	32.4	-	19.3	23.7	32.1
E	19.3	24.0	32.3	19.3	23.9	32.4	-	19.4	24.0	32.2
F	19.6	24.1	32.4	19.6	24.3	32.4	-	19.6	24.1	32.2
G	19.8	24.5	32.8	19.8	24.7	32.8	-	20.0	24.6	32.7
H	20.0	24.6	33.0	19.9	24.7	32.9	-	20.1	24.7	32.8
I	20.0	24.6	33.0	19.9	24.7	32.9	32.8	19.9	24.7	32.9
3	19.2	23.6	31.1	19.2	23.6	31.1	31.1	19.2	23.6	31.1
4	19.2	23.7	31.2	19.2	23.7	31.2	31.2	19.2	23.7	31.2
5	18.9	23.3	30.8	18.9	23.3	30.7	-	18.9	23.3	30.7
6	18.7	22.9	30.0	18.6	22.9	30.0	-	18.6	22.8	30.0
7	17.3	21.4	28.4	17.3	21.4	28.4	-	17.3	21.4	28.4
8	16.1	19.9	27.3	16.1	19.9	27.2	-	16.1	19.9	27.2
9**	15.9	19.8	27.0	15.9	19.8	27.0	27.0	15.9	19.8	27.0

* Gage locations shown on plates 3 and 21.
\- No data obtained.

** Tailwater control gage.

TABLE E

FLOW CONDITIONS DOWNSTREAM FROM LEFT POWERHOUSE UNIT

Unit Discharge 22,000 cfs
Runout Slope 1V on 2H

1:40-scale model

Tailwater Elev	Remarks
	Parallel walls downstream from powerhouse (preliminary study).
16	Strong but irregular boil moved between 30 and 110 ft downstream from powerhouse along the left wall. Slight impact on right wall between 125 and 225 ft with upstream flow for 170 ft below powerhouse.
25	Strong, continuous boil appeared generally between 35 and 125 ft and occasionally to 150 ft downstream from powerhouse. An occasional boil appeared in mid-flume 175 ft from powerhouse and rolled downstream to 250 ft. Slight impact on right wall between 100 and 250 ft caused upstream flow for 175 ft with slight eddy in mid-flume at 75 ft (a common condition for all plans tested because of the isolation of a single unit in the model instead of the effect of an adjacent unit also discharging downstream).
	Angled wall at downstream entrance (photograph 14).
16	Major boil between 50 and 120 ft downstream from powerhouse. Boil trailed around the corner and along the angled wall at downstream entrance. Boil was spasmodic and occurred 50 per cent of time. Boil occurred in mid-flume at 150 ft and full width of flume at 200 ft downstream from powerhouse. Downstream flow along full length of left wall made a "good" condition for fish passage.
25	Boil occurred between 50 and 120 ft downstream from powerhouse but not as severe as with TW 16. An occasional boil reached 130 ft and trailed around corner to follow along angled wall and hit wall of trash sluice. Irregular boil occurred in mid-flume at 160 ft and covered full width of flume 225 ft downstream from powerhouse. A "good" condition for fish passage.
	Downstream entrance moved 58.9 ft downstream (photograph 15).
16	Boil along left wall between 50 and 175 ft almost continuous. Moderate eddy at downstream entrance. Boil in mid-flume at 125 ft and full width at 175 ft. Plan produced "fair" conditions which could be made [illegible] by adding an angled wall at the downstream entrance to eliminate the eddy.
25	Boil occurred along left wall between 70 and 175 ft about 50 per cent of time. Mild eddy at downstream entrance. Boil in mid-flume at 150 ft and full width at 190 ft. Conditions at the fishway entrance were "fair to good".
	Mirror image of north shore with deflector over draft tube depressed 15° (photograph 16).
16	Boil along left wall was centered 175 ft downstream from powerhouse and over the change in invert [illegible]. Upwelling also occurred 100 ft out from left wall at same station. Flow downstream along the wall was very rough between 200 and 250 ft owing to these disturbances. Upstream flow occurred along the left wall between 175 and 120 ft where the flow struck the downstream entrance wall and created a counter clockwise eddy at the fishway entrance. Conditions along the left wall were "poor" for fish passage. Upwelling generally occurred the full width of the flume at 175 ft from the powerhouse.
25	Boil along left wall at 175 ft was dampened by the higher tailwater. Upwelling centered 50 ft from left wall joined boil along wall and carried downstream for an additional 65 ft. Upstream flow along the left wall between 175 and 120 ft created a mild eddy by the downstream fishway entrance. Upwelling in mid-flume occurred between 160 and 230 ft from the powerhouse. Conditions were still "poor" for fish passage along the left wall.
	Mirror image of north shore with alternative invert near left wall and deflector over draft tube depressed 15° (photograph 17).
[illegible]	Boil surfaced 25 ft from left wall 175 ft below powerhouse. Upwelling along left wall was moderate between 175 and 225 ft below powerhouse. Flow along wall was upstream between 175 and 120 ft and created a mild eddy at the downstream fishway entrance. Major boil was centered between 150 and 175 ft below powerhouse and 40 ft from left wall. Upwelling occasionally occurred full width of flume between 150 and 225 ft with a random upwelling in mid-flume between 125 and 150 ft below powerhouse. Conditions for fish passage were "fair to poor".
[illegible]	Boil surfaced spasmodically 25 ft from left wall 175 ft below powerhouse. Mild upwelling along left wall between 175 and 225 ft. Flow was upstream between 175 and 120 ft with very mild eddy at downstream entrance to fishway. Upwelling occurred full width of flume between 150 and 225 ft with some concentration on left side. General conditions were "fair to poor".

TABLE F

VELOCITIES ALONG FACE OF SITE C POWERHOUSE

Plan C-2 Approach
Plan B Training Wall

Unit	Location[2]	River Discharge in CFS[1]									
		360,000		510,000		700,000		850,000		1,420,000	
		Direction[3]	Velocity[4]	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
11	T	90 L	4	90 L	5	90 L	6	90 L	5	90 L	10
	M	5 L	3	20 L	4	20 L	4	45 L	6	45 L	9
	B	45 L	4	45 L	4	80 L	7	45 L	5	90 L	9
12	T	90 L	4	90 L	4	90 L	4	90 L	4	90 L	8
	M	0	4	5 L	4	30 L	4	10 L	7	10 L	7
	B	0	3	5 L	4	45 L	5	45 L	7	10 L	6
13	T	90 L	2	0/90 L	2	0/180	2	0/180	2	90 R	7
	M	0	4	0	4	0	4	0	4	45 R	5
	B	0	3	0	4	10 R	4	10 R	5	90 R	6
14	T	0/90 L	2	0/90 R	3	90 R	4	100 R	4	90 R	7
	M	0	4	0	4	10 R	5	45 R	5	60 R	10
	B	0	3	45 R	3	80 R	4	45 R	5	90 R	10
15	T	0/90 L&R	2	90 R	2	100 R	5	90 R	7	90 R	9
	M	0	4	5 R	4	45 R	5	45 R	5	60 R	9
	B	0	3	45 R	4	30 R	5	80 R	7	80 R	11
16	T	90 R	2	90 R	3	90 R	6	90 R	7	90 R	8
	M	0	4	5 R	4	20 R	5	45 R	5	45 R	7
	B	20 R	3	80 R	4	80 R	6	80 R	7	90 R	10
17	T	90 R	3	90 R	4	90 R	6	90 R	5	90 R	5
	M	0	4	5 R	4	20 R	4	10 R	6	45 R	5
	B	45 R	4	80 R	5	45 R	5	80 R	7	90 R	9
18	T	90 R	4	90 R	3	90 R	4	90 R	4	90 R	4
	M	5 R	4	10 R	3	30 R	4	20 R	4	45 R	4
	B	80 R	4	80 R	4	10 R	5	45 R	5	90 R	6

NOTES: 1. Site C powerhouse 160,000 cfs except with river discharge 1,420,000 cfs, then 117,000 cfs.
2. T=5-ft depth, M=mid-depth, B=5 ft above bottom.
3. Direction of flow in degrees right or left from perpendicular to powerhouse.
4. Velocity in feet per second.

TABLE G

VELOCITIES ALONG FACE OF SITE C POWERHOUSE

Plan C-3 Approach

Unit	Location[2]	River Discharge in CFS[1]									
		36[illegible]		[illegible]		700,000		850,000		1,420,000	
		Direction[3]	Velocity[4]	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
11	T	90 L	5	90 L	4	10 L	2-6	30 L	5	90 L	5-11
	M	20 L	4	20 L	5	30 L	6	30 L	5	20 L	6
	B	10 L	4	10 L	4	30 L	4	45 L	5	90 L	7
12	T	90 L	3	90 L	4	40 L	4	90/180 L	3-5	90 L	2-9
	M	20 L	5	20 L	4	0	5	0	5	0	6
	B	20 L	4	0	4	0	4	10 L	6	20 L	7
13	T	90 L	2	90 L	2	180	3	90/180 R	3	90 R	2-6
	M	10 L	4	0	4	10 R	5	0	5	20 R	6
	B	0	4	0	3	20 R	4	10 R	5	45 R	7
14	T	90 L	2	90/180 R	2-4	100 R	4	100 R	5	90 R	7-9
	M	0	4	0	4	20 R	5	30 R	5	70 R	10
	B	0	3	30 R	4	45 R	5	45 R	7	90 R	9
15	T	90 L&R	2	110 R	4	90 R	4	100 R	6	90 R	7-13
	M	0	4	10 R	4	30 R	7	45 R	5	60 R	10
	B	0	3	30 R	4	70 R	6	45 R	6	80 R	11
16	T	90 R	2	90 R	4	90 R	5	90 R	7	90 R	10
	M	0	4	20 R	5	30 R	6	45 R	8	60 R	9
	B	0/90 R	2	45 R	4	70 R	7	60 R	8	70 R	9
17	T	90 R	3	90 R	4	90 R	5	90 R	7	90 R	7
	M	0	4	20 R	4	20 R	5	45 R	6	45 R	8
	B	90 R	3	45 R	5	60 R	7	60 R	8	60 R	9
18	T	90 R	4	90 R	4	90 R	5	90 R	6	90 R	6
	M	0	4	10 R	4	10 R	5	30/60 R	5-6	45 R	5
	B	45 R	5	30 R	5	45 R	5	10 R	5	45 R	5

NOTES: 1. Site C powerhouse 160,000 cfs except with river discharge 1,420,000 cfs, then 117,000 cfs.
2. T=5-ft depth, M=mid-depth, B=5 ft above bottom.
3. Direction of flow in degrees right or left from perpendicular to powerhouse.
4. Velocity in feet per second.

[illegible] H

[illegible]

[illegible] Approach

Unit	Location[2]	36[illegible]		[illegible]		[illegible]		[illegible]		1,42[illegible]	
		Direction[3]	Velocity[4]	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
11	T	90 L	4	90 L	4	90 L	6	90 L	8	90 L	8
	M	20 L	4	20 L	5	45 L	5	30 L	7	0/90 L	5-8
	B	30 L	4	0/90 L	4-5	45 L	6	45 L	9	90 L	8
12	T	90 L	5	90 L	4	100 L	4	90 L	7	90L/90R	8
	M	20 L	4	10 L	5	0/45 L	6	20 L	8	0	8
	B	90 L	4	0/90 L	4	45 L	7	20 L	7	90 L	8
13	T	90 L	3	0/180	3	0/180	3	0/180	4	90 R	8
	M	0	4	0	4	0	4	0	5	45 R	8
	B	Swirl	2	45 R	4	Swirl	5	0	6	60 R	9
14	T	0/180	2	Swirl	3	90 R	4	90 R	5	90 R	11
	M	0	5	10 R	4	20 R	4	60 R	7	60 R	11
	B	Swirl	2-3	45 R	4	45 R	5	60 R	6	80 R	11
15	T	0/180	2	90 R	4	90 R	6	90 R	7	90 R	10
	M	0	5	10 R	4	45 R	7	45 R	9	70 R	10
	B	0/90 R	3	70 R	4	80 R	7	50 R	9	80 R	11
16	T	90 R	2	90 R	4	90 R	7	90 R	9	90 R	9
	M	0	4	10 R	4	20 R	5	45 R	9	60 R	9
	B	90 R	3	80 R	4	80 R	8	80 R	9	80 R	11
17	T	90 R	4	90 R	4	90 R	6	90 R	6	90 R	8
	M	0	4	10 R	4	10 R	5	45 R	8	45 R	8
	B	80 R	4	60 R	6	80 R	8	80 R	9	80 R	9
18	T	90 R	4	90 R	4	90 R	4	90 R	5	90 R	4
	M	10 R	4	10 R	4	10 R	5	45 R	6	45 R	7
	B	30 R	4	60 R	5	60 R	6	0	4	80 R	8

NOTES:
1. Site C powerhouse 160,000 cfs except with river discharge 1,420,000 cfs, then 117,000 cfs.
2. T=5-ft depth, M=mid-depth, B=5 ft above bottom.
3. Direction of flow in degrees right or left from perpendicular to powerhouse.
4. Velocity in feet per second.

TABLE H

TABLE I

SECOND POWERHOUSE OPERATION SCHEDULE

MINIMUM RIVER FLOW

Second Powerhouse Units Operating	1981				1982						
	Mar	May	Oct	Nov	Jan	Feb	Apr	Jun	Jul	Aug	Sep
	River Discharge in 1000 CFS										
	137	190	68	89	106	126	150	188	100	80	69
	Spillway Discharge in 1000 CFS										
	11	50	0	1	4	4	8	12	12	12	1
	Existing Powerhouse Discharge in 1000 CFS										
	126	140	28	28	42	42	42	56	28	28	28
	Second Powerhouse Discharge in 1000 CFS										
18	0	20	20	20	20	20	20	20	20	20	20
17			20	20	0	20	20	20	20	0	0
16				20	20	20	20	20	0	0	0
15					20	20	20	20	0	0	0
14							20	20	0	0	0
13								20	0	0	0
12									20	20	0
11											20

TABLE J

SECOND POWERHOUSE OPERATION SCHEDULE

MAXIMUM RIVER FLOW

Second Powerhouse Units Operating	1981 Apr	1981 May	1981 Aug	1981 Sep	1981 Dec	1982 Jan	1982 Apr	1982 May	1982 Jul	1982 Sep
	River Discharge in 1000 CFS									
	258	313	170	147	215	250	258	313	240	147
	Spillway Discharge in 1000 CFS									
	118	173	10	9	15	30	18	53	2	0
	Existing Powerhouse Discharge in 1000 CFS									
	140	140	140	98	140	140	140	140	98	28
	Second Powerhouse Discharge in 1000 CFS									
18	0	20	20	20	20	20	20	20	20	20
17				20	20	20	20	20	20	0
16					20	20	20	20	20	0
15						20	20	20	20	20
14							20	20	20	20
13								20	20	20
12									20	20
[illegible]										19

TABLE J

Photograph 1. Site D powerhouse and navigation lock.

Photograph 2. Si
na
pl
o

Photograph 4. Site E powerhouse and navigation lock. Flow conditions in upstream navigation approach channel, channel entrance, river discharge 600,000 cfs, spillway discharge 458,000 cfs, forebay elevation 74.0.

Photograph 6. Upstream approach channel, forebay elevation 74.0.

Photograph 7. Downstream channel, tailwater elevation 39.1.

Site C powerhouse and Bradford Island excavation plan 8. Flow conditions with river discharge 600,000 cfs, site C powerhouse discharge 220,000 cfs, spillway discharge 238,000 cfs.

Entering upstream entrance of site C navigation lock.

Exiting upstream entrance of site C navigation lock.

Photograph 8. Site C powerhouse and navigation lock with Bradford Island plan 8 excavation, towboat operation.

River discharge 600,000 cfs
Site C powerhouse discharge 220,000 cfs
Spillway discharge 238,000 cfs

Photograph 9. Dry bed showing temporary simulation of existing upstream end of Bradford Island.

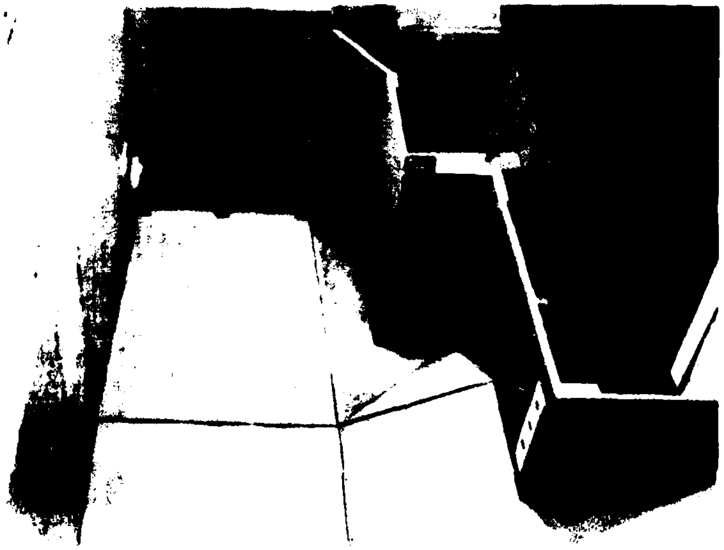
Plan C-2 tailrace

Plan C-4 tailrace

Photograph 10. Site C powerhouse, flow conditions with modified tailrace channel designs. River discharge 220,000 cfs; site C powerhouse discharge 220,000 cfs.

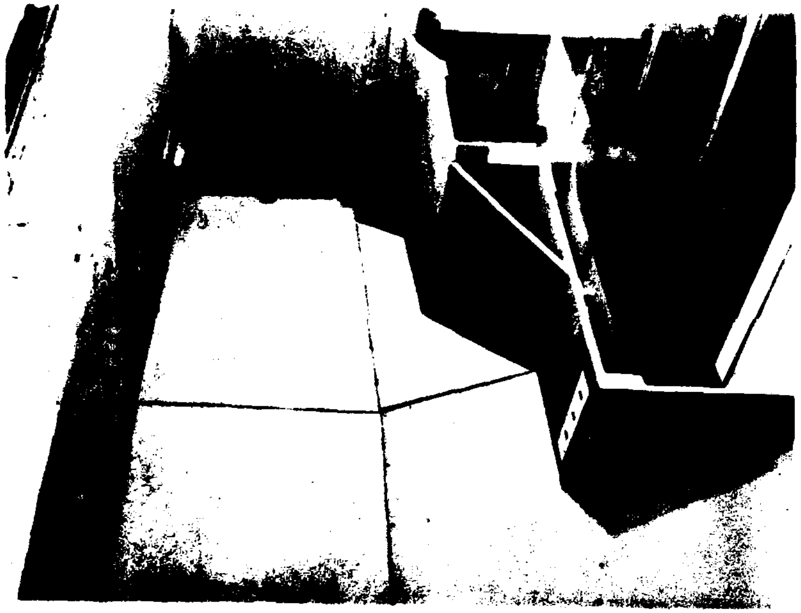
Photograph 11. Dry bed showing site C-3 powerhouse (final design location) with original design channels.

Photograph 12. Dry bed of 1:80-scale draft tube runout model.
Draft tube invert slope 1V:3.5H.
Runout slope 1V:4H.

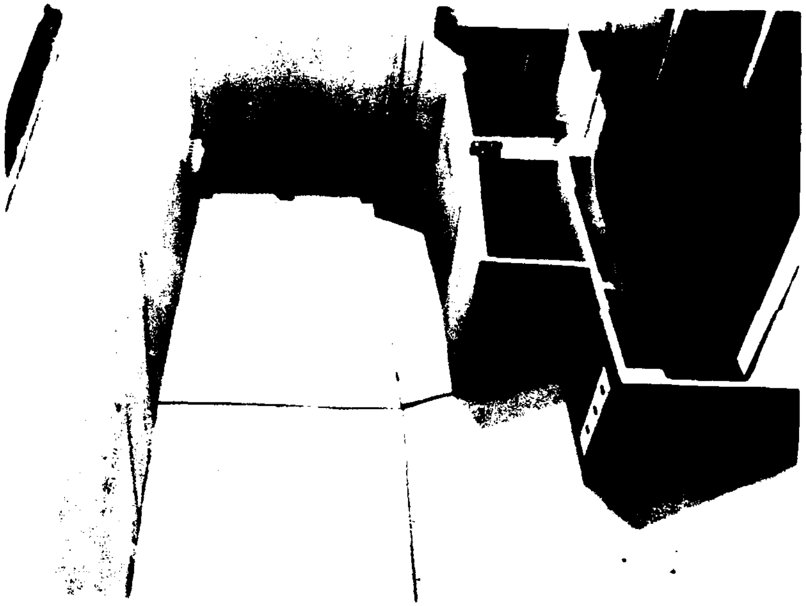


Photograph 13. Dry bed of 1:40-scale model of powerhouse tailrace wall showing original design left wall.

Site C-3 powerhouse.

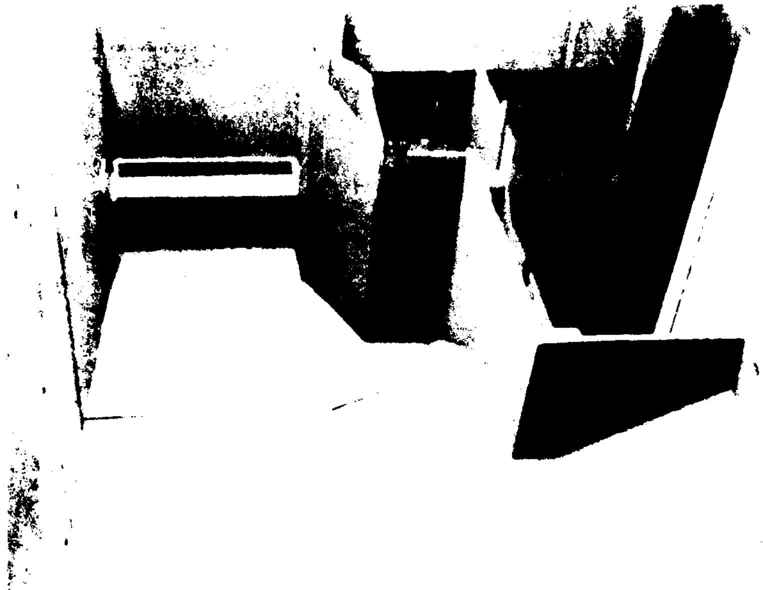


Photograph 14. Dry bed of powerhouse tailrace wall showing angled wall at downstream fishway entrance with alternative invert along left wall.

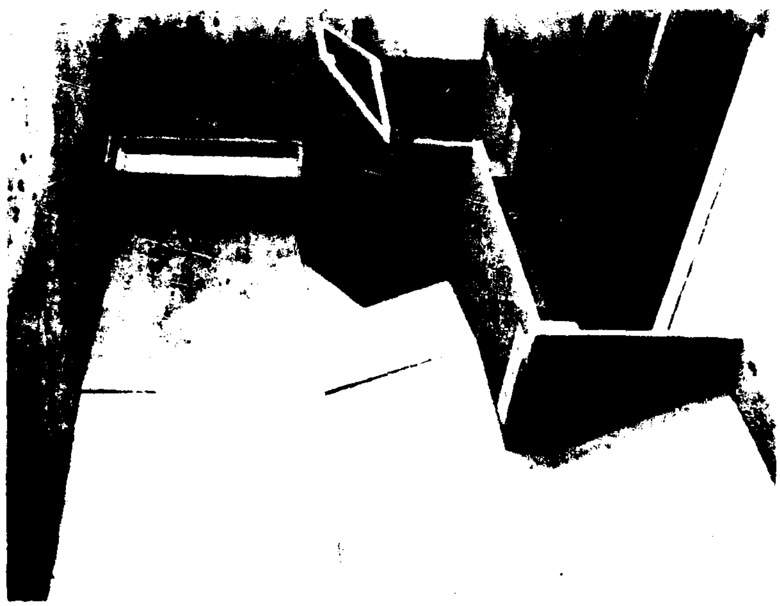


Photograph 15. Dry bed with downwstream fishway entrance located 58.9-feet downstream from original location with alternative invert along left wall.

Site C-3 Powerhouse tailrace wall.



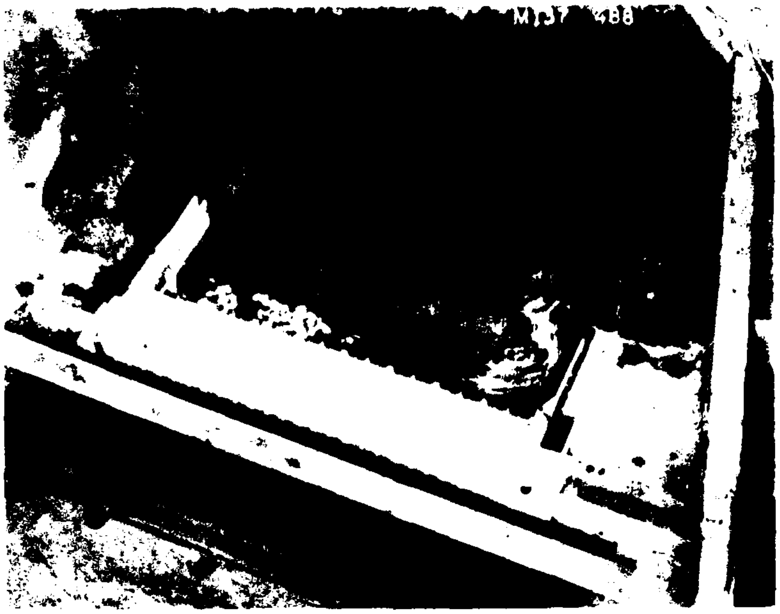
Photograph 16. Dry bed with deflector over draft tube exit with original invert along left wall.



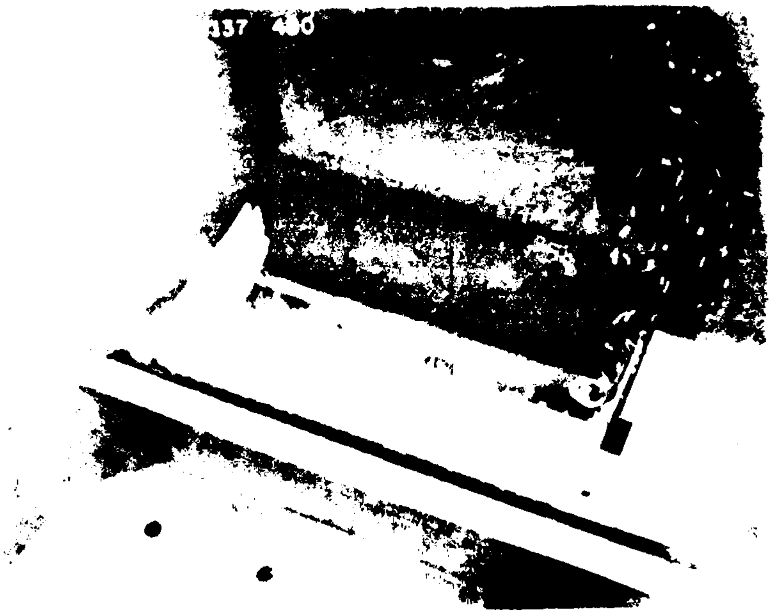
Photograph 17. Dry bed with deflector over draft tube exit with alternative invert along left wall.

Site C-3 powerhouse tailrace wall.

Photograph 18. Site C-3 powerhouse with plan C-6A tailrace channel. Flow conditions with river discharge 309,400 cfs, site C-3 powerhouse discharge 160,000 cfs, spillway discharge 2,400 cfs, fish facility discharge 6,000 cfs, tailwater elevation 25.1.



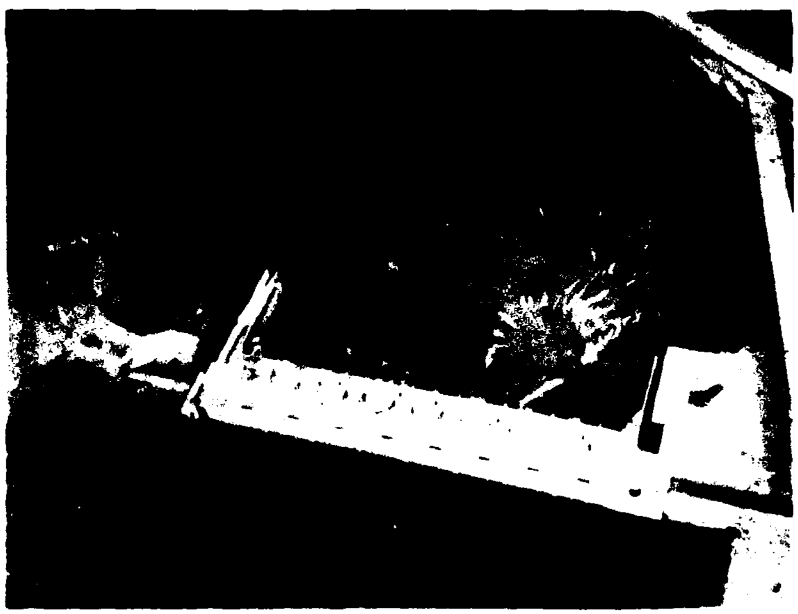
Photograph 19. Original design.



Photograph 20. Constant runout slope 1V:3.38H to elevation -20.

Original design (plan C-6A) tailrace channel. North fishway entrance flow conditions. River discharge 360,000 cfs; powerhouse discharge 166,000 cfs; gage T-2 elevation [illegible].0.

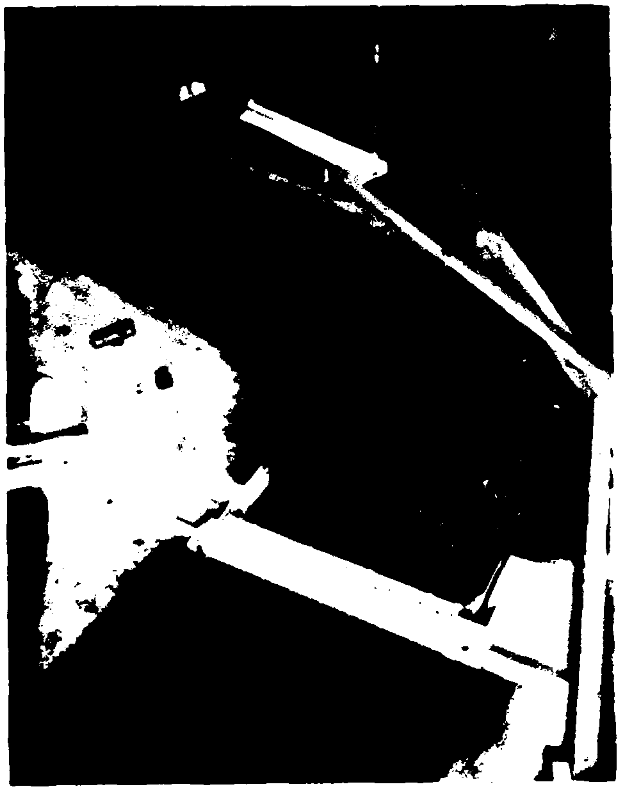
Photograph 21. Training wall at elevation -25.0



Photograph 22. Training wall at elevation -38.0.

Original design (plan C-6A) tailrace channel. North fishway entrance flow conditions. River discharge 360,000 cfs; powerhouse discharge 166,000 cfs; gage T-2 elevation 28.0.

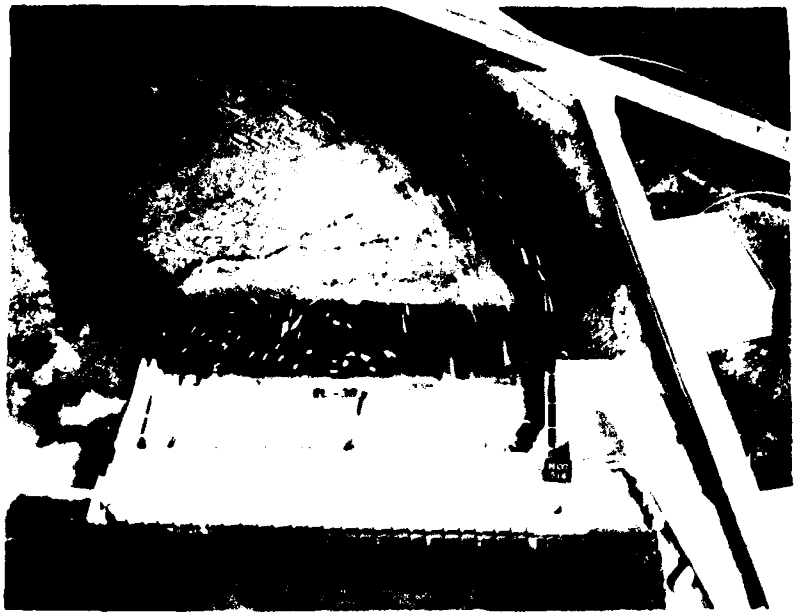
Photograph 23. Plan C-6B tailrace channel. Flow conditions, river discharge 309,400 cfs; site C-3 powerhouse discharge 160,000 cfs; existing powerhouse discharge 141,000 cfs; spillway discharge 2,400 cfs; gage T-2 elevation 25.7.



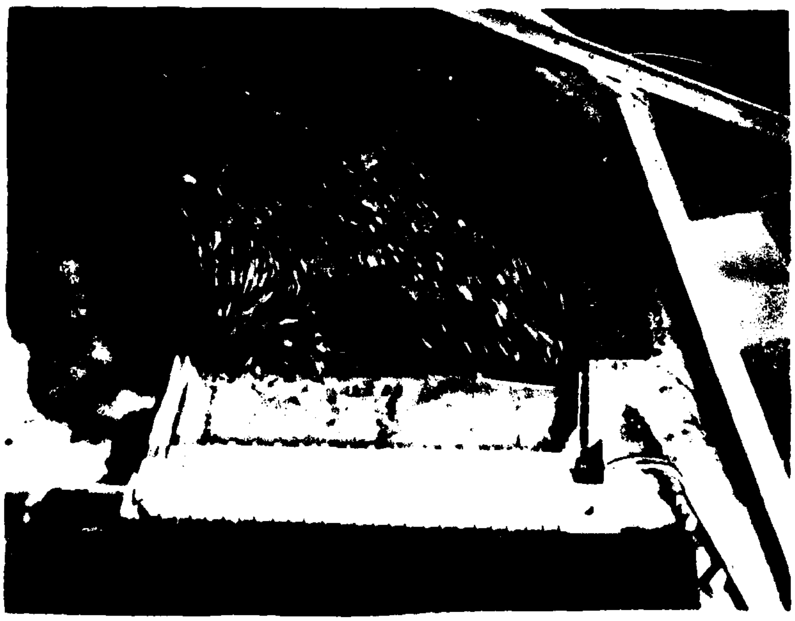
Photograph 24. Plan C-6C tailrace channel (invert to elevation -10).

Photograph 25. Plan C-6D tailrace channel (Invert to elevation -10 with bank realignments).

Flow conditions with river discharge 208,400 cfs; site C-3 powerhouse discharge 160,000 cfs; existing powerhouse discharge 40,000 cfs; spillway discharge 2,400 cfs



Units 17 and 18 operating.

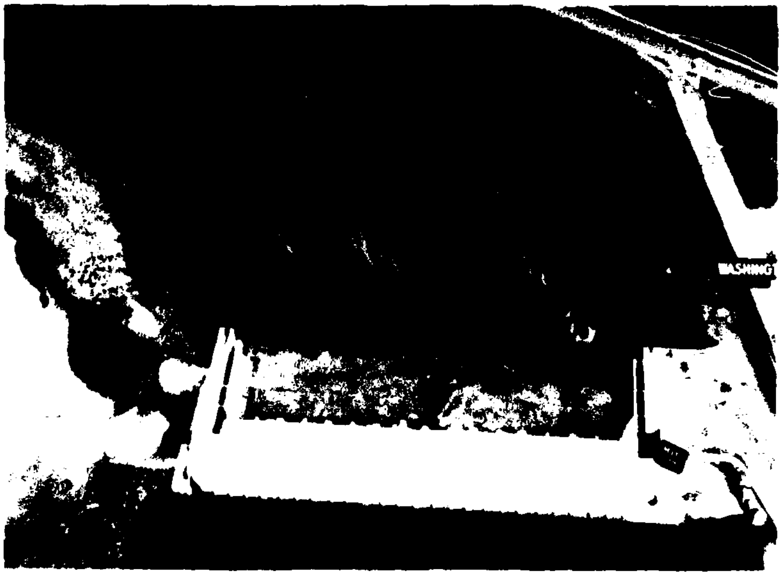


Units 11, 16, 17, and 18 operating.

Photograph 26. Plan C-6E (final design) tailrace channel. Fishway entrance flow conditions, river discharge 80,000 cfs; site C-3 powerhouse discharge 34,400 cfs; existing powerhouse discharge 40,000 cfs; site C-3 powerhouse fish facility discharge 3,200 cfs; gage T-2 elevation 9.7.

Photograph 27. Plan C-6E (final design) tailrace channel. Fishway entrance flow conditions, river discharge 168,400 cfs; site C-3 powerhouse discharge 160,000 cfs; site C-3 powerhouse fish facilities discharge 6,000 cfs, gage T-2 elevation 16.6.

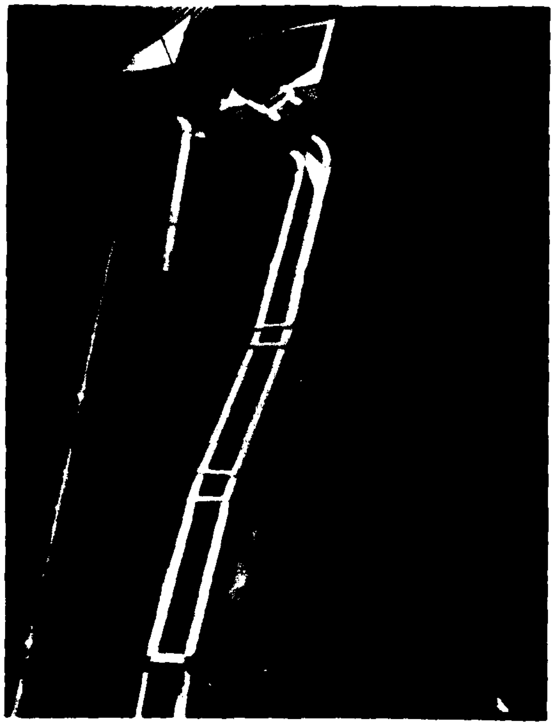
Photograph 28. River discharge 228,400 cfs; existing powerhouse discharge 60,000 cfs; spillway discharge 2,400 cfs; gage T-2 elevation 20.5.



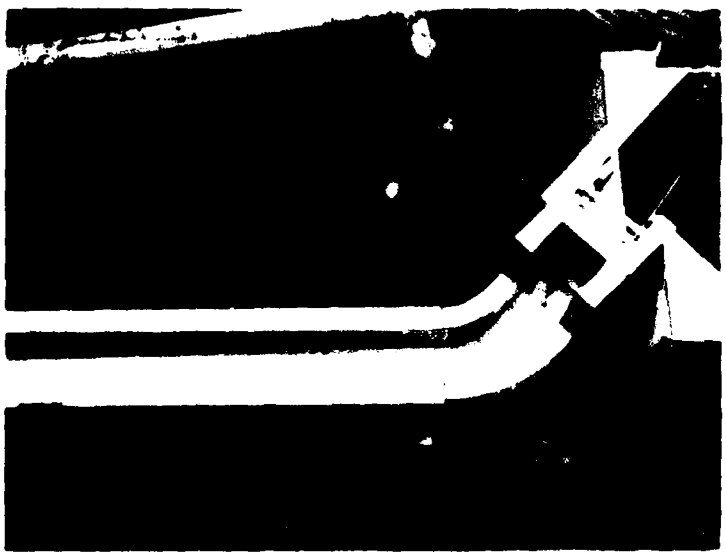
Photograph 29. River discharge 360,000 cfs; existing powerhouse discharge 141,000 cfs; spillway discharge 53,000 cfs; gage T-2 elevation 27.9.

Plan C-6E (final design) tailrace channel. Fishway entrance flow conditions, site C-3 powerhouse discharge 160,000 cfs; site C-3 powerhouse fish facilities discharge 6,000 cfs.

Photograph 30. Site C-3 powerhouse, plan C-1 approach channel. Flow conditions with river discharge 510,000 cfs; site C-3 powerhouse discharge 160,000 cfs; existing powerhouse discharge 141,000 cfs; spillway discharge 203,000 cfs; forebay elevation 73.7.

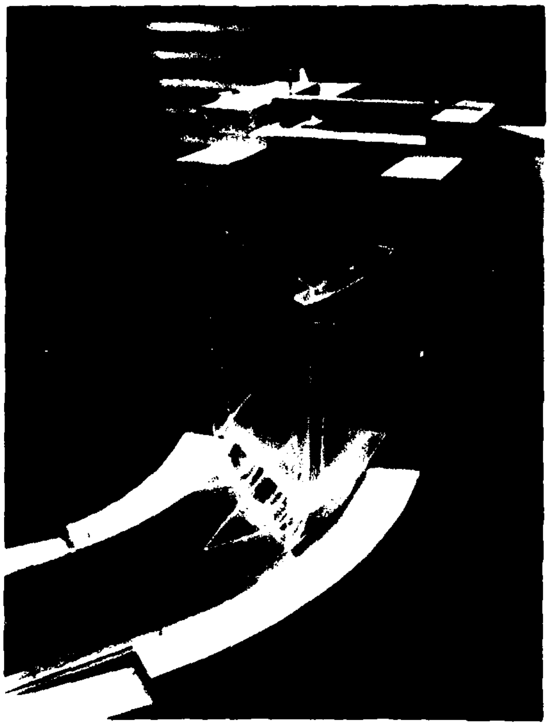


Overall view



Chute intake, control gate,
and upstream bend

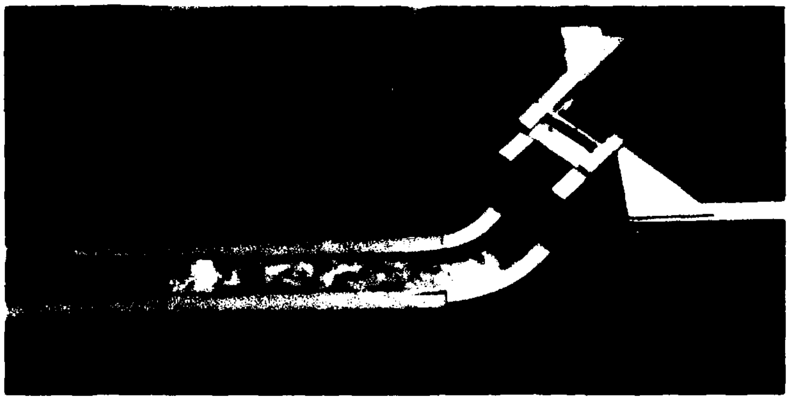
Photograph 31. Ice and trash chute, dry bed of initial plan without fishwater intake (roof removed).



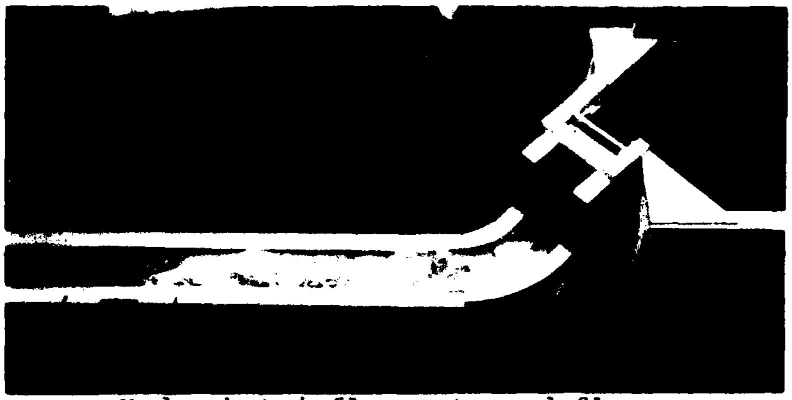
Revised headwall

Emergency fishwater supply intake

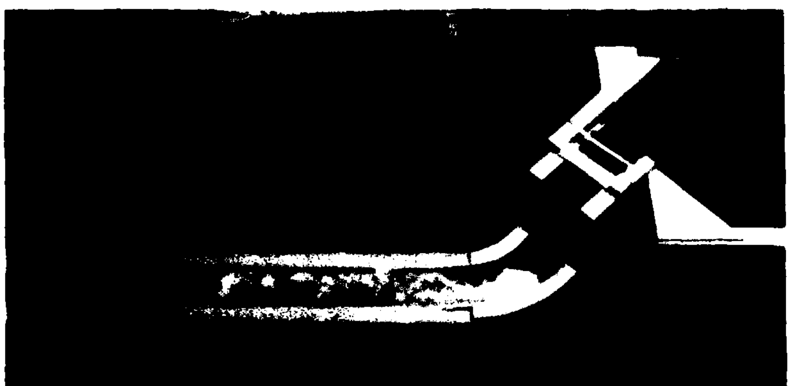
Photograph 32. Ice and trash chute, dry bed of revised model (clear roof) with revised headwall and emergency fishwater supply intake.



Undershot inflow, sloped floor



Undershot inflow, stepped floor



Overshot inflow, stepped floor

Photograph 33. Ice and trash chute, hydraulic jump in chute with discharge 2,200 cfs.

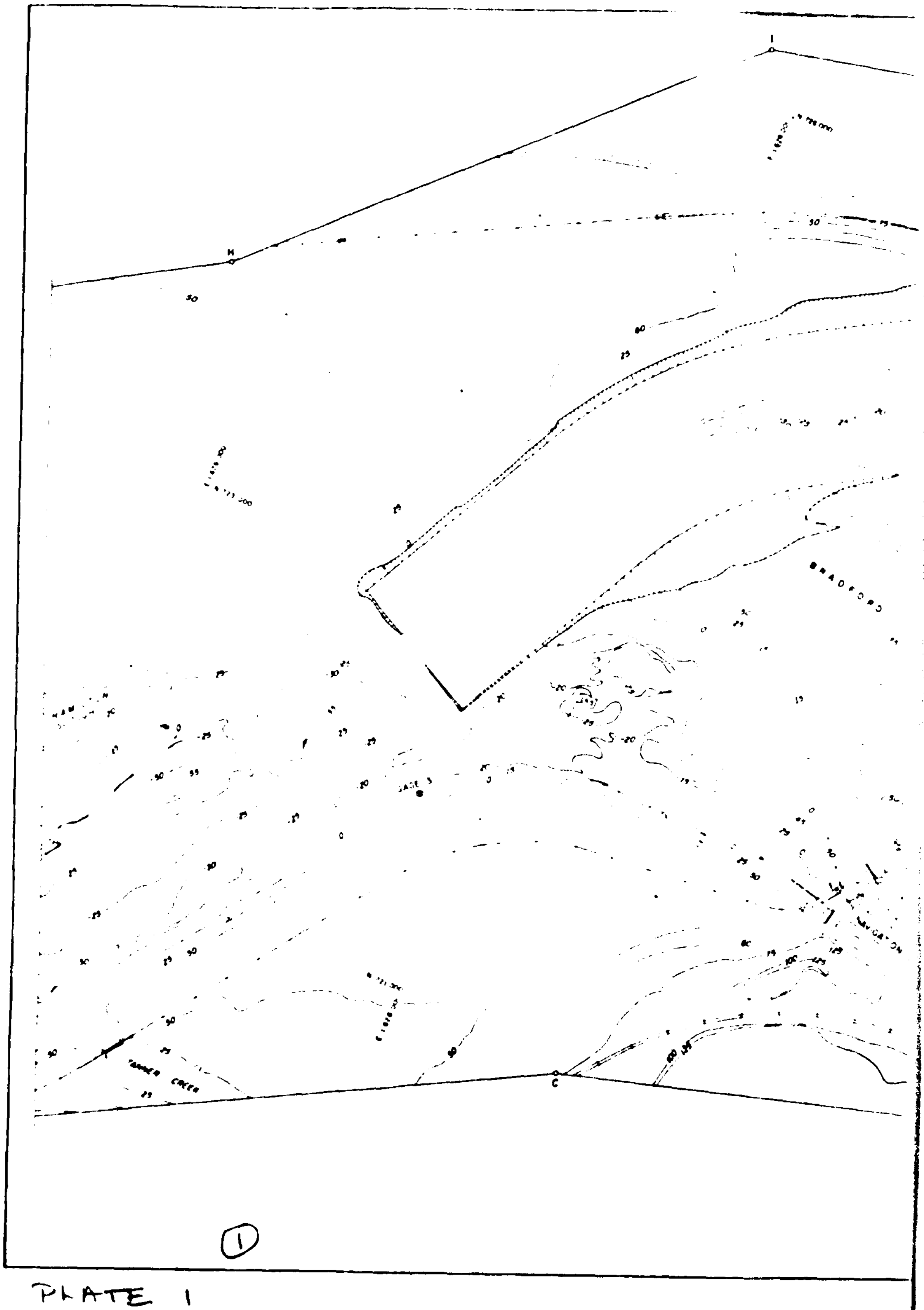
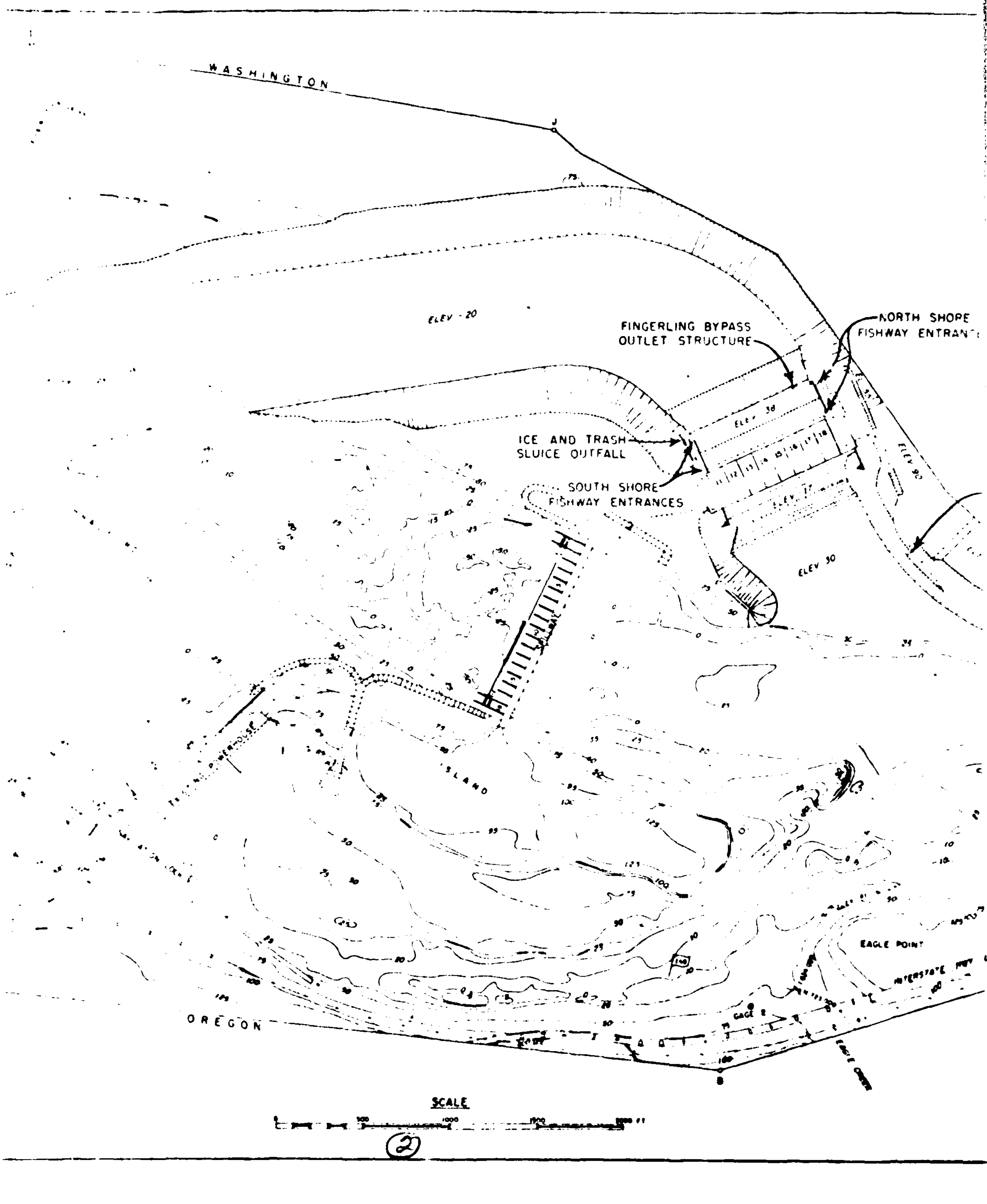
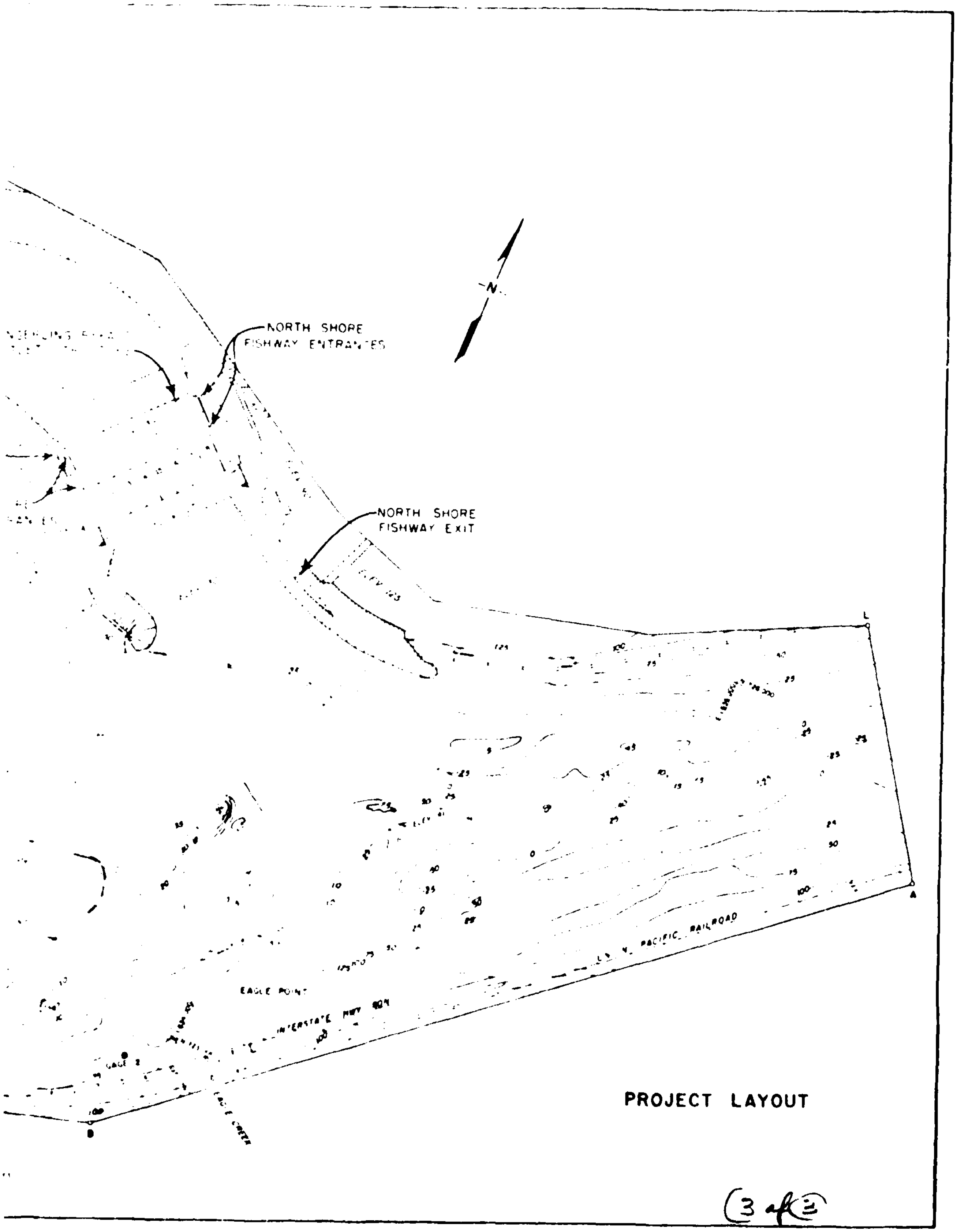


PLATE 1

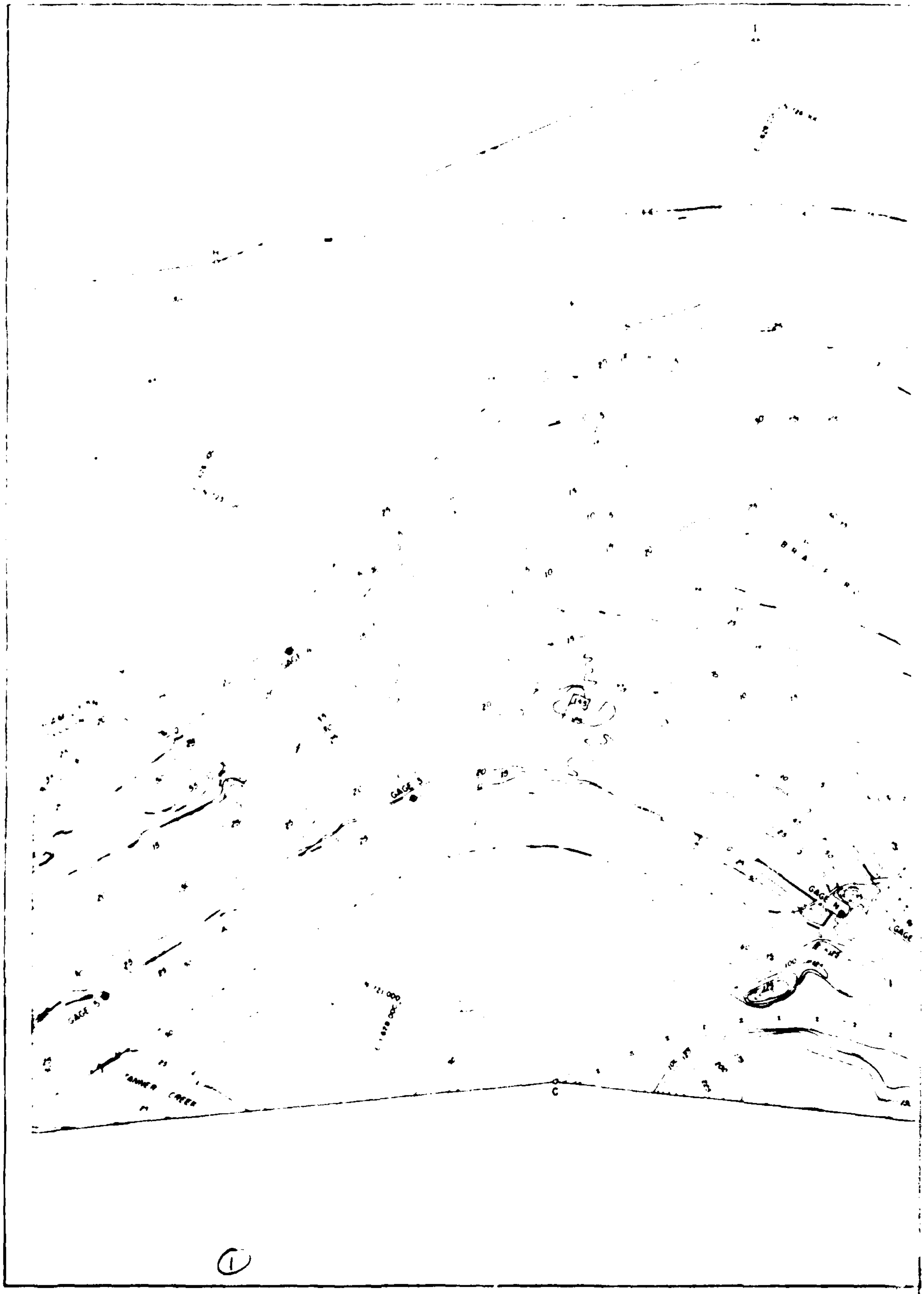

WASHINGTON
ELEV -20
FINGERLING BYPASS
OUTLET STRUCTURE
NORTH SHORE
FISHWAY ENTRANCE
ICE AND TRASH
SLUICE OUTFALL
SOUTH SHORE
FISHWAY ENTRANCES
ELEV 30
ISLAND
EAGLE POINT
OREGON
SCALE
0
500
1000
1500
2000 FT

(2)


NORTH SHORE
FISHWAY ENTRANCES
NORTH SHORE
FISHWAY EXIT
N
EAGLE POINT
INTERSTATE HWY 80N
U. P. PACIFIC RAILROAD
GAGE 2
EAGLE CREEK
L
A
B
PROJECT LAYOUT

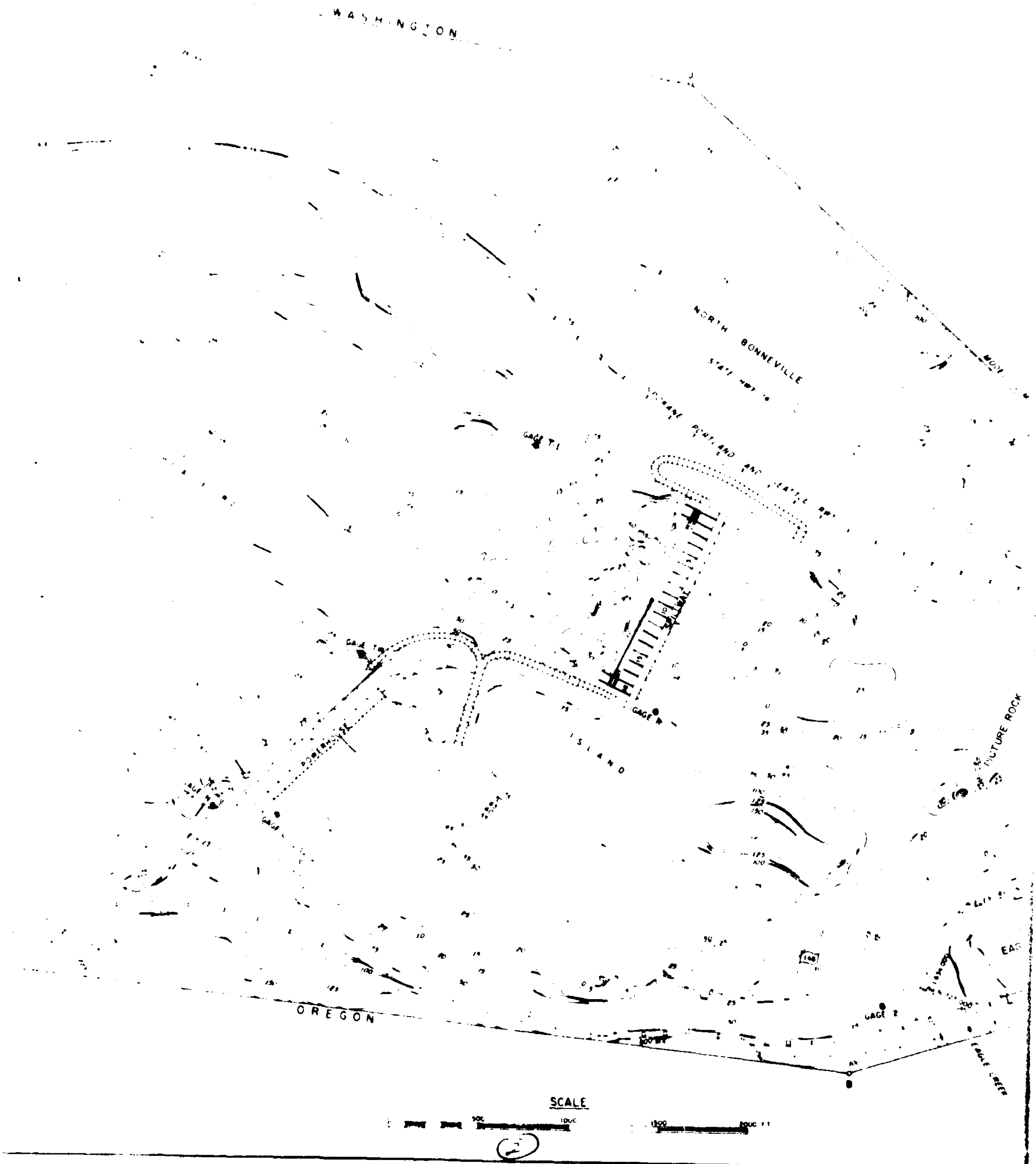
(3 of 3)

PLATE 1



1

PLATE 2


WASHINGTON
NORTH BONNEVILLE
ISLAND
OREGON
PICTURE ROCK
EAGLE CREEK
SCALE

MODEL LAYOUT

(3 of 6)

PLATE 2

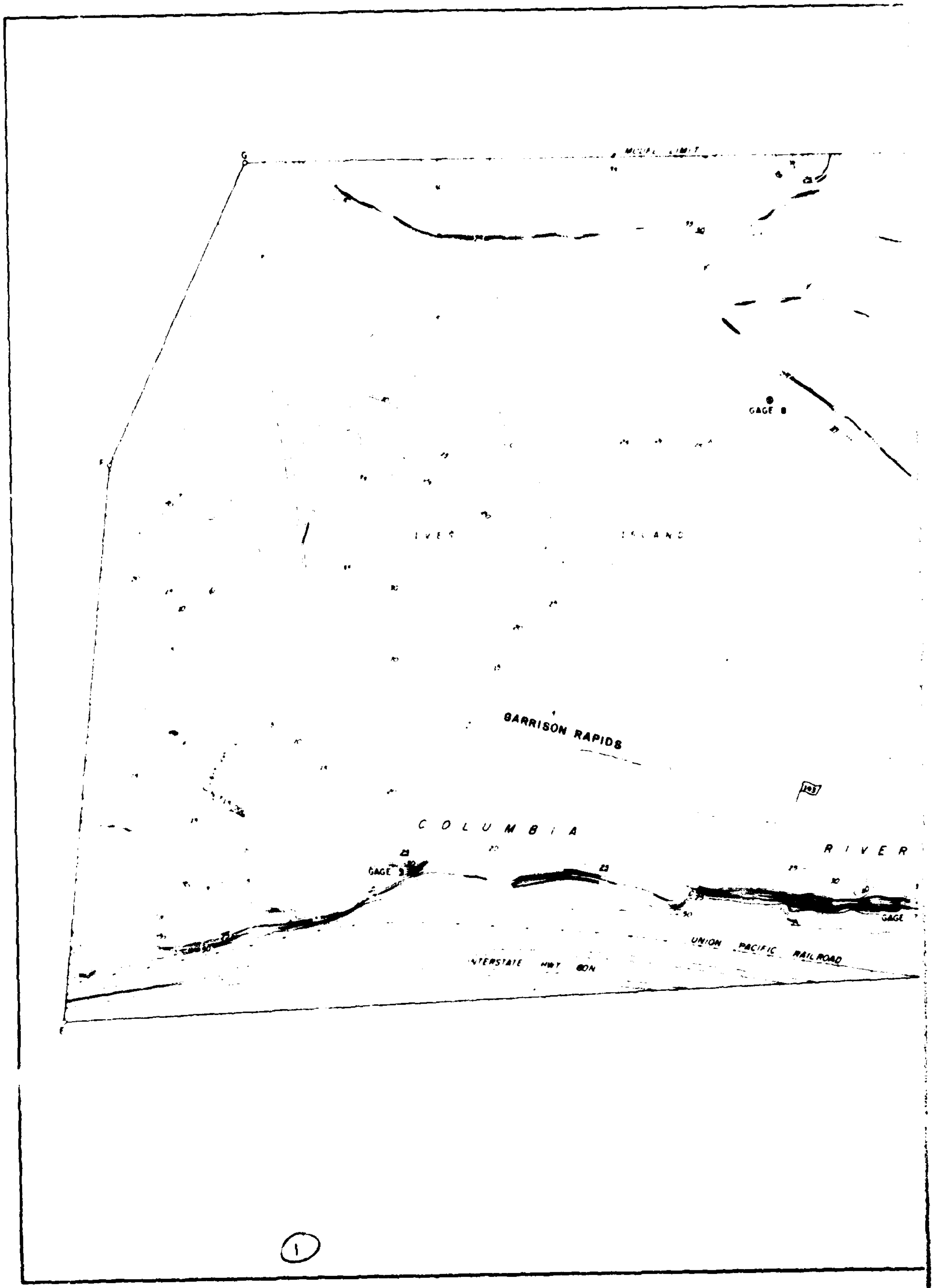
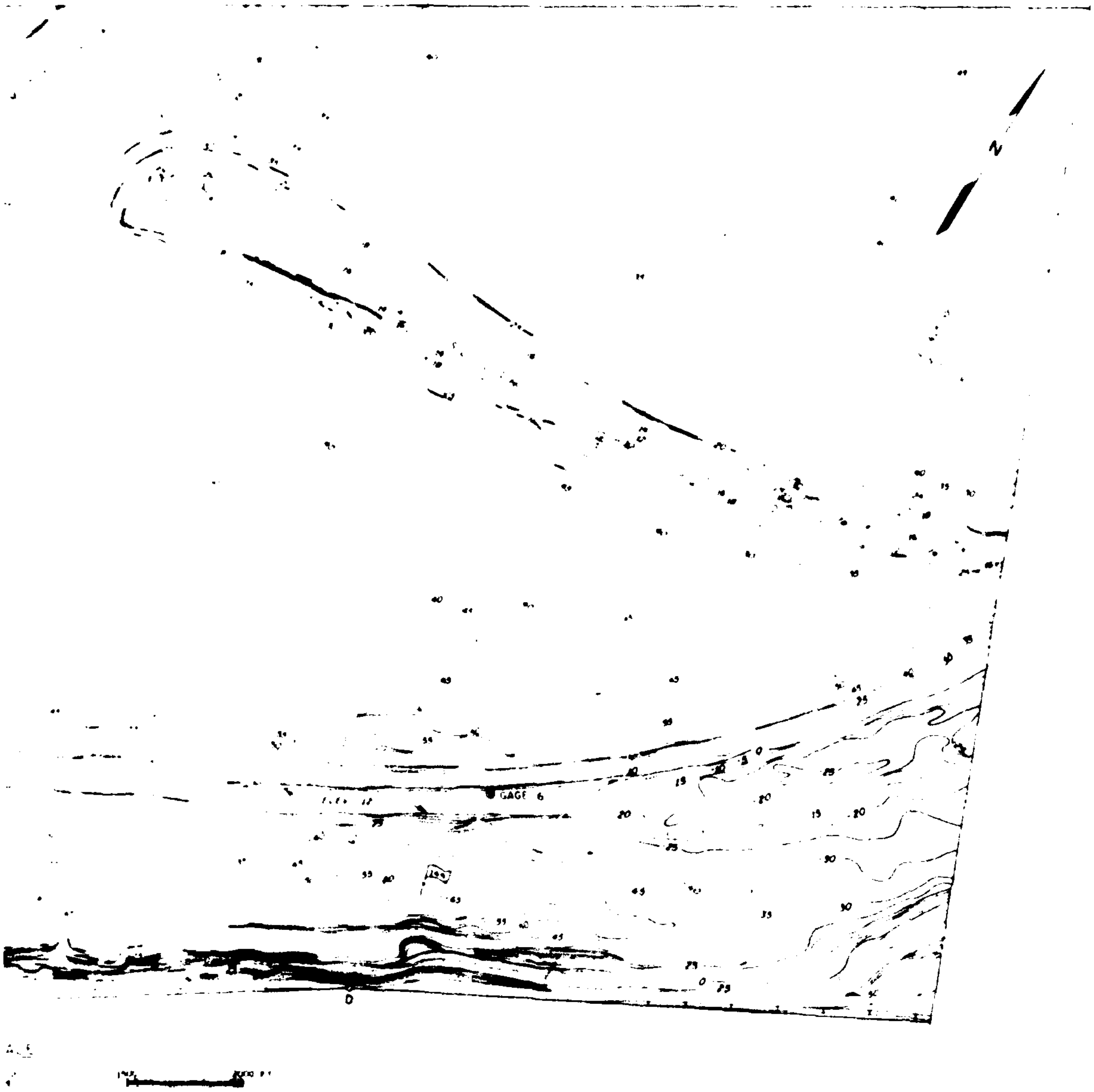

GAGE 8
BARRISON RAPIDS
COLUMBIA
RIVER
GAGE 3
UNION PACIFIC RAILROAD
INTERSTATE HWY 80N

PLATE 3

(2)

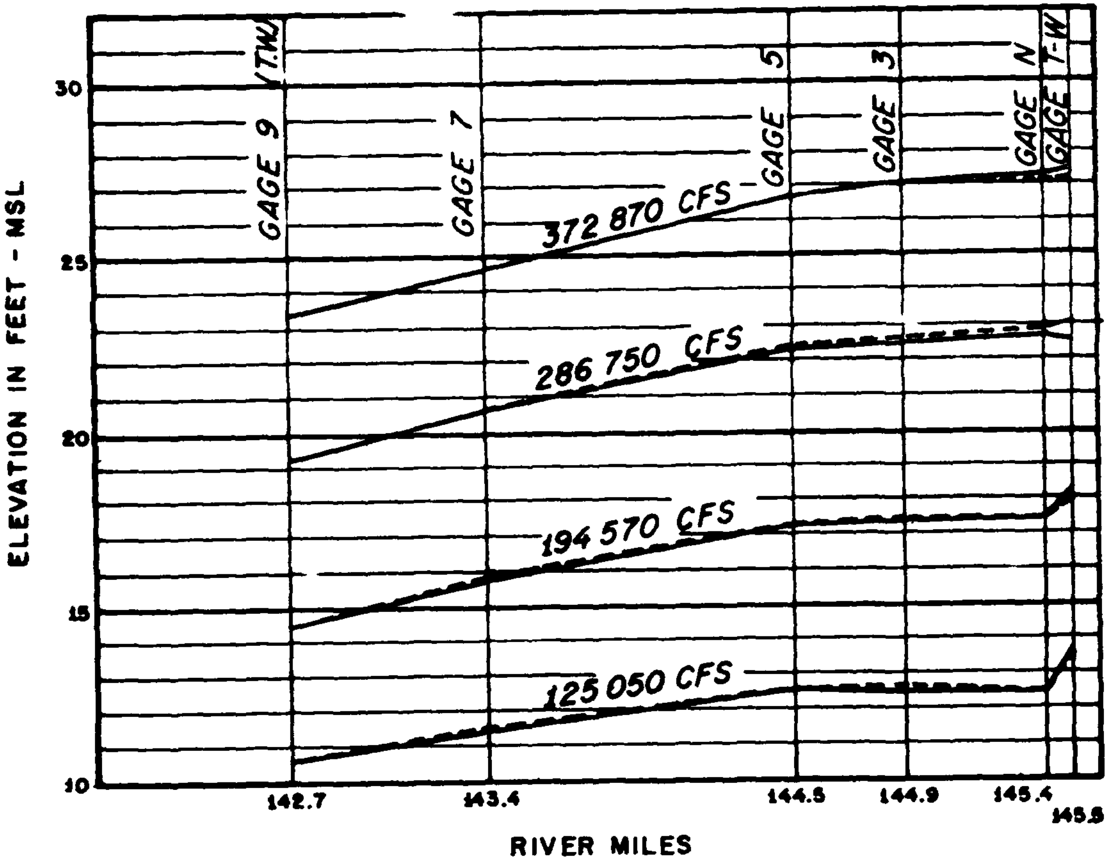


MODEL LAYOUT

(3 of 5)

SHEET 2 OF 2

PLATE 3



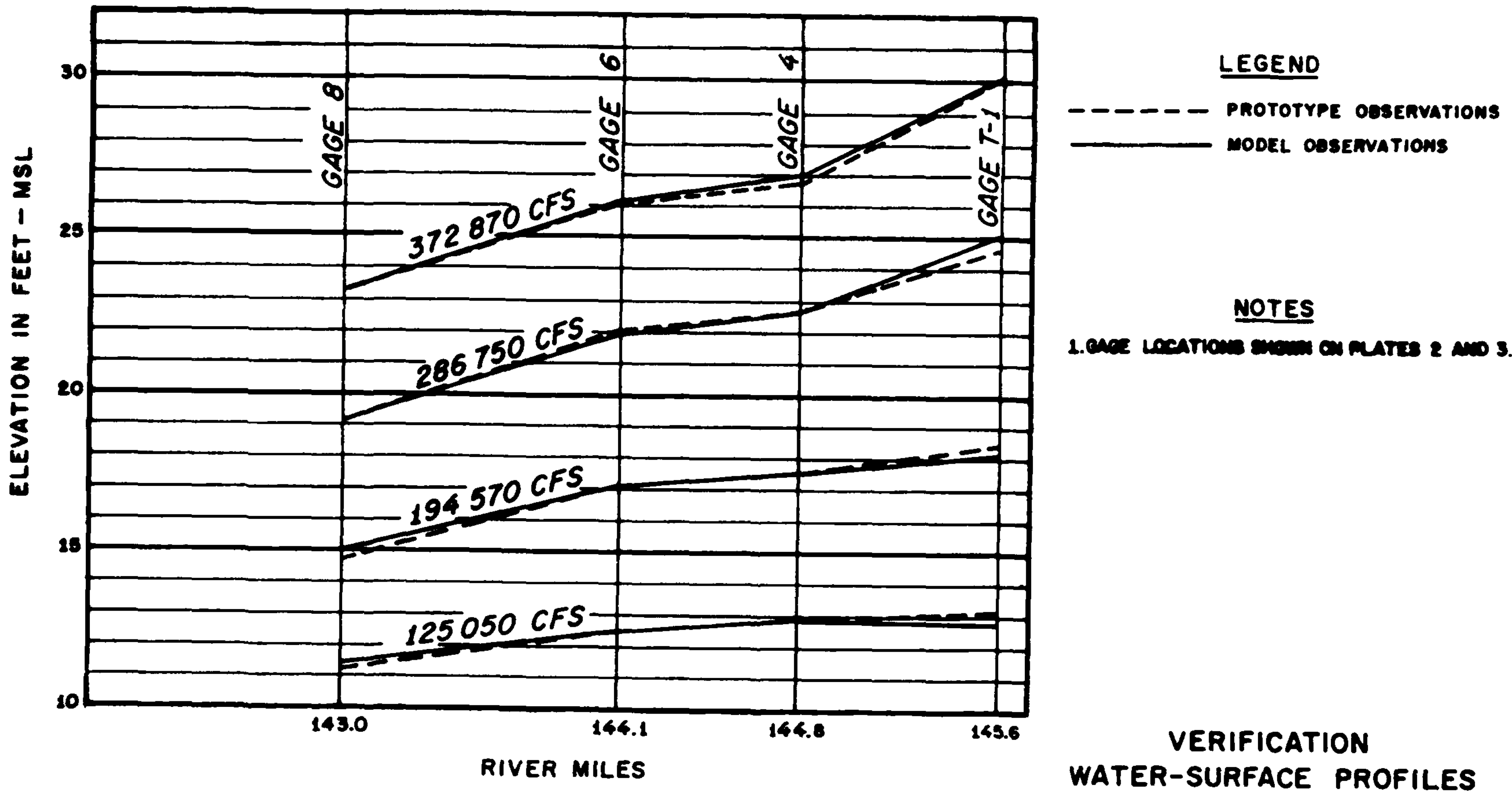
LEGEND

- – – – – PROTOTYPE OBSERVATIONS
- ——— MODEL OBSERVATIONS

NOTES

1. GAGE LOCATIONS SHOWN ON PLATES 2 AND 3.

VERIFICATION
WATER-SURFACE PROFILES
LEFT BANK

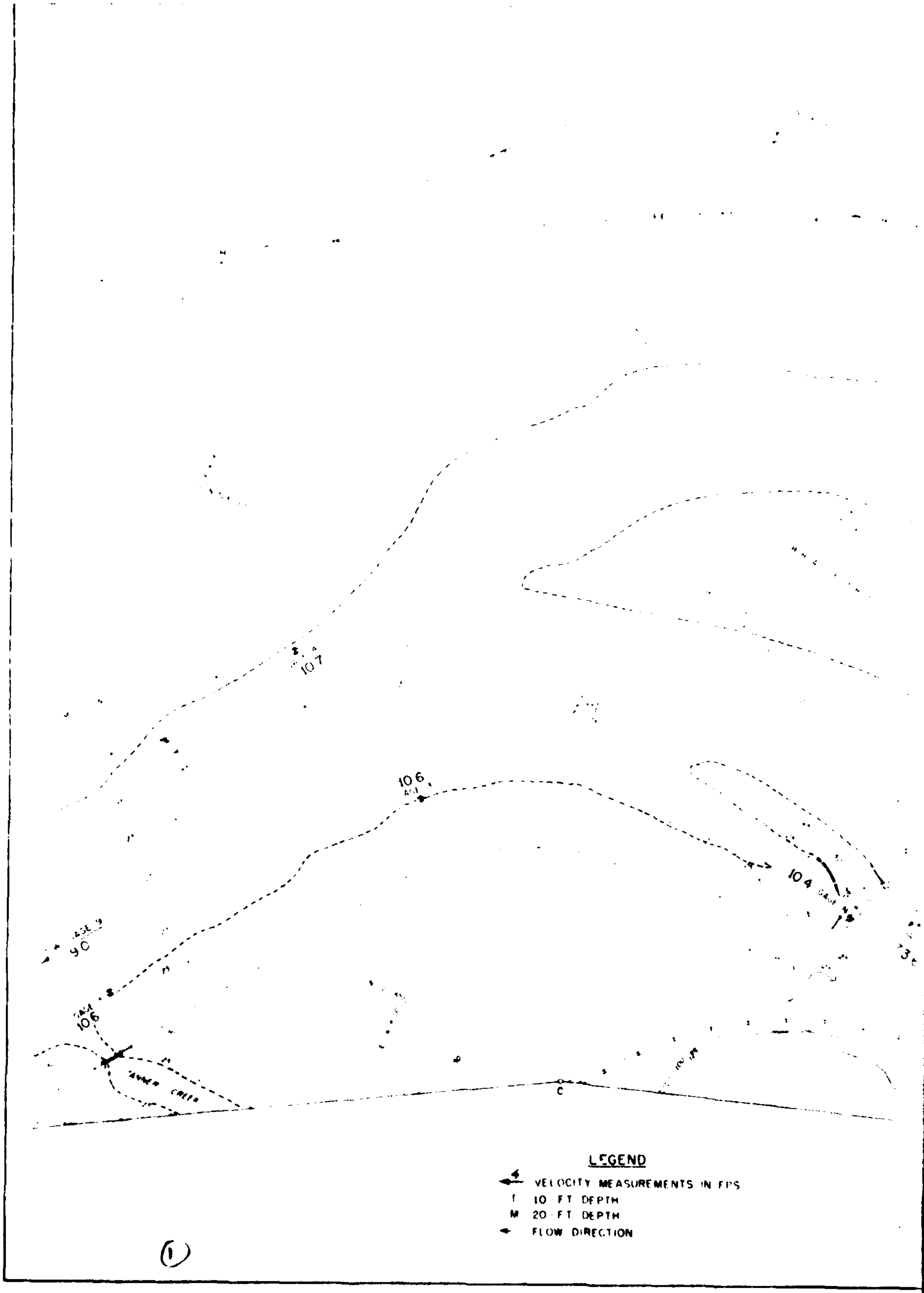


NOTES

1. GAGE LOCATIONS SHOWN ON PLATES 2 AND 3.

VERIFICATION
WATER-SURFACE PROFILES
RIGHT BANK

PLATE 5

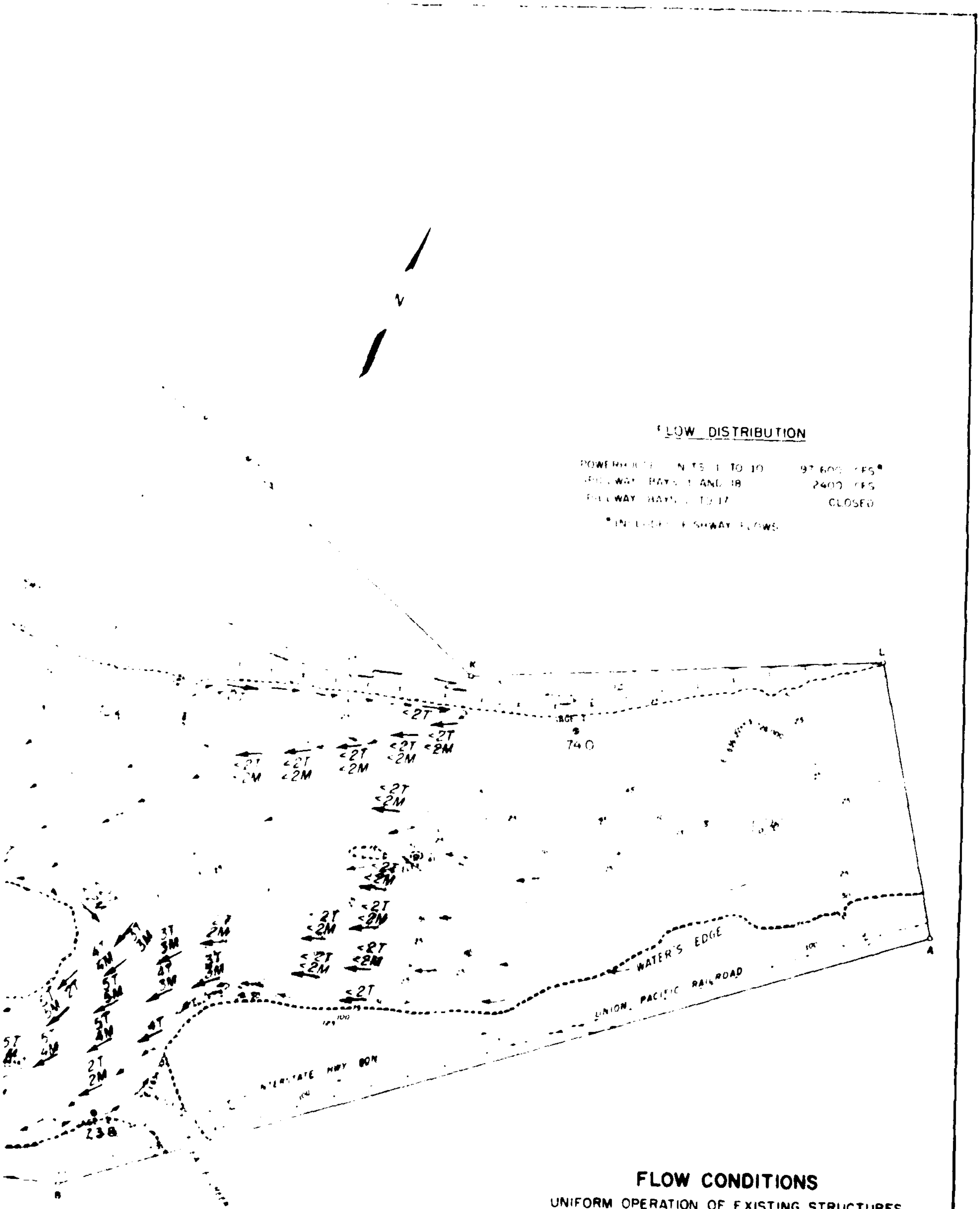

107
106
104
90
106
C
LEGEND
VELOCITY MEASUREMENTS IN FPS
T 10 FT DEPTH
M 20 FT DEPTH
FLOW DIRECTION

(1)

PLATE 6


NORTH BONNEVILLE
SLACK
ISLAND
OREGON
GAGE 740
GAGE 740
GAGE 738
736
116
SCALE
EAGLE CREEK

(2)



FLOW CONDITIONS

UNIFORM OPERATION OF EXISTING STRUCTURES
RIVER DISCHARGE 100 000 CFS

(5)

PLATE 6

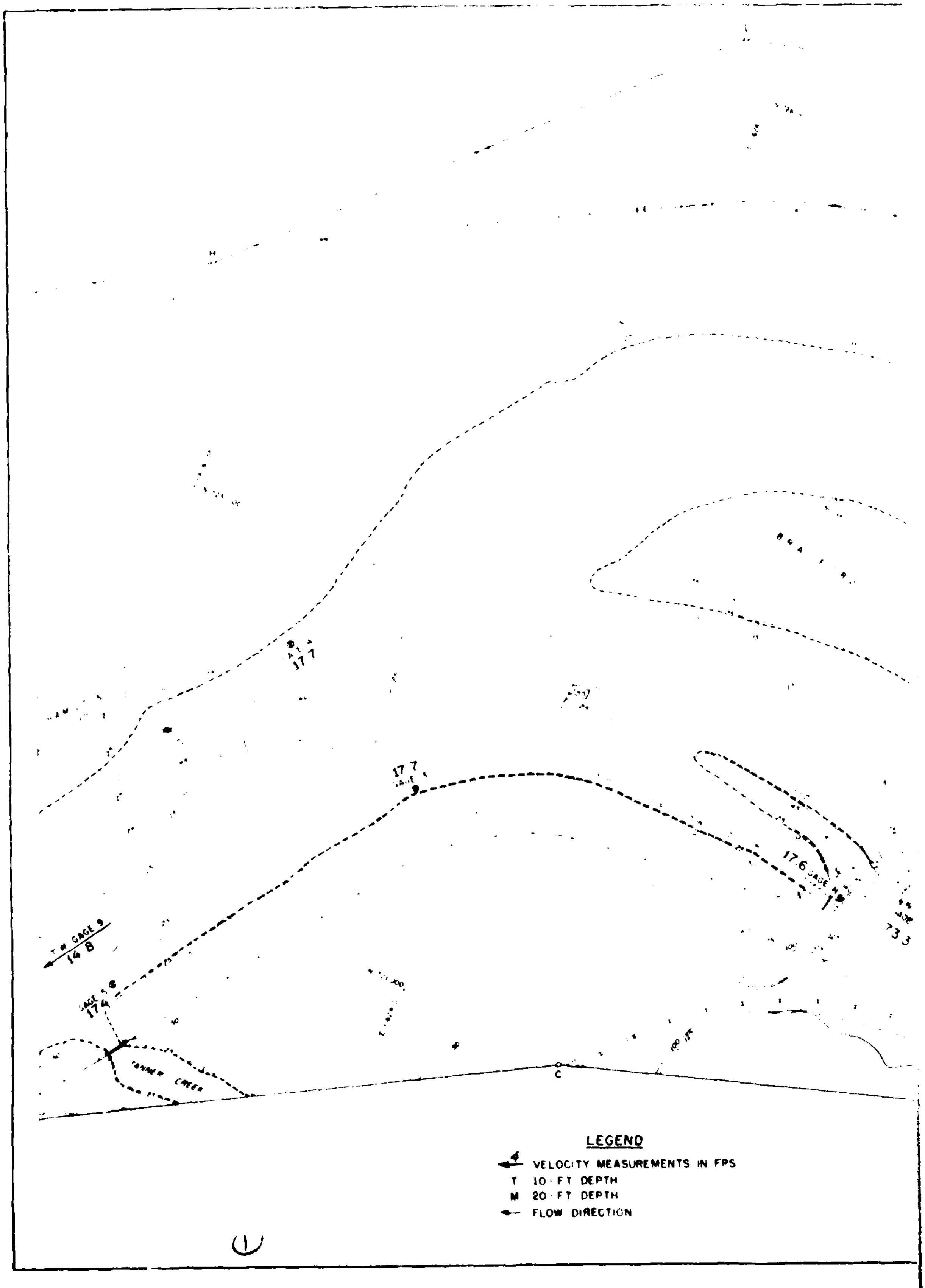
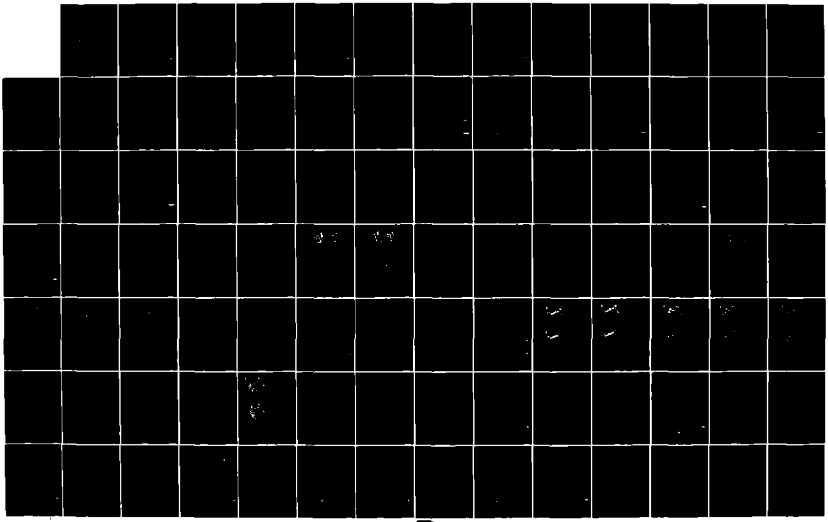

T.W. GAGE 5
14.8
17.7
17.7
17.6
17.4
TANNER CREEK
C
LEGEND
VELOCITY MEASUREMENTS IN FPS
T 10-FT DEPTH
M 20-FT DEPTH
FLOW DIRECTION
(1)

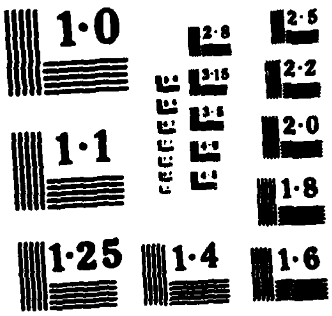
PLATE 1

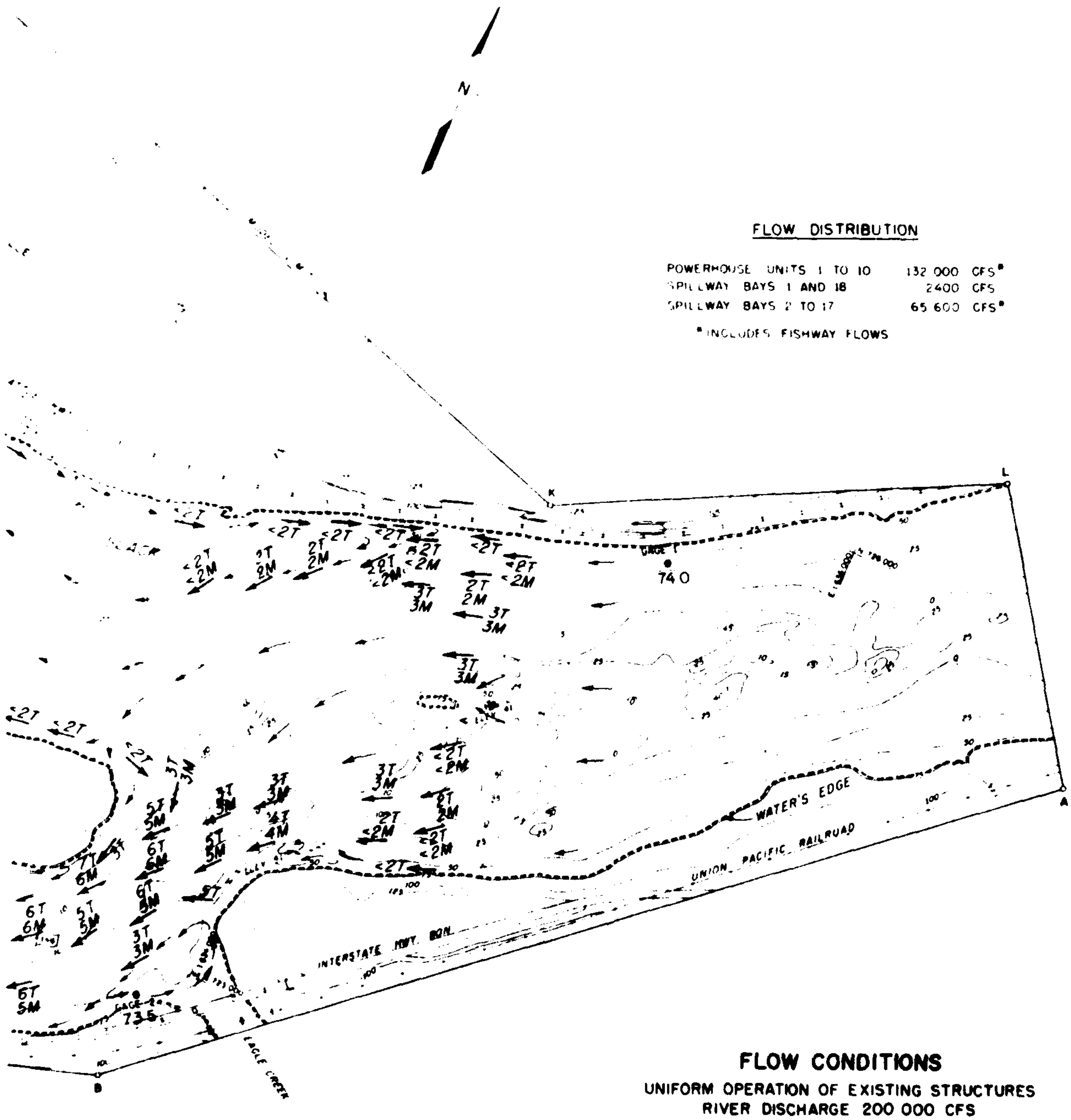

WASHINGTON
NORTH BONNEVILLE
SLACK
ISLAND
OREGON
GAGE T1
191
182
733
GAGE 740
740
<2T
<2M
2T
2M
3T
3M
4T
4M
5T
5M
6T
6M
7T
GAGE 2
735
INTERSTATE
EAGLE CREEK
SCALE

AD A146 974 BONNEVILLE SECOND POWERHOUSE COLUMBIA RIVER OREGON AND WASHINGTON HYDRAUL..(U) ARMY ENGINEER DIV NORTH PACIFIC BONNEVILLE OR DIV HYDRAULIC L.. W CONBERE AUG 84 2/3

UNCLASSIFIED TR 137 1 F/G 10/2 NL




1·0
2·8
2·5
3·15
2·2
3·5
2·0
1·1
4·0
4·5
1·8
1·25
1·4
1·6



FLOW DISTRIBUTION

POWERHOUSE UNITS 1 TO 10	132 000 CFS*
SPILLWAY BAYS 1 AND 18	2400 CFS
SPILLWAY BAYS 2 TO 17	65 600 CFS*

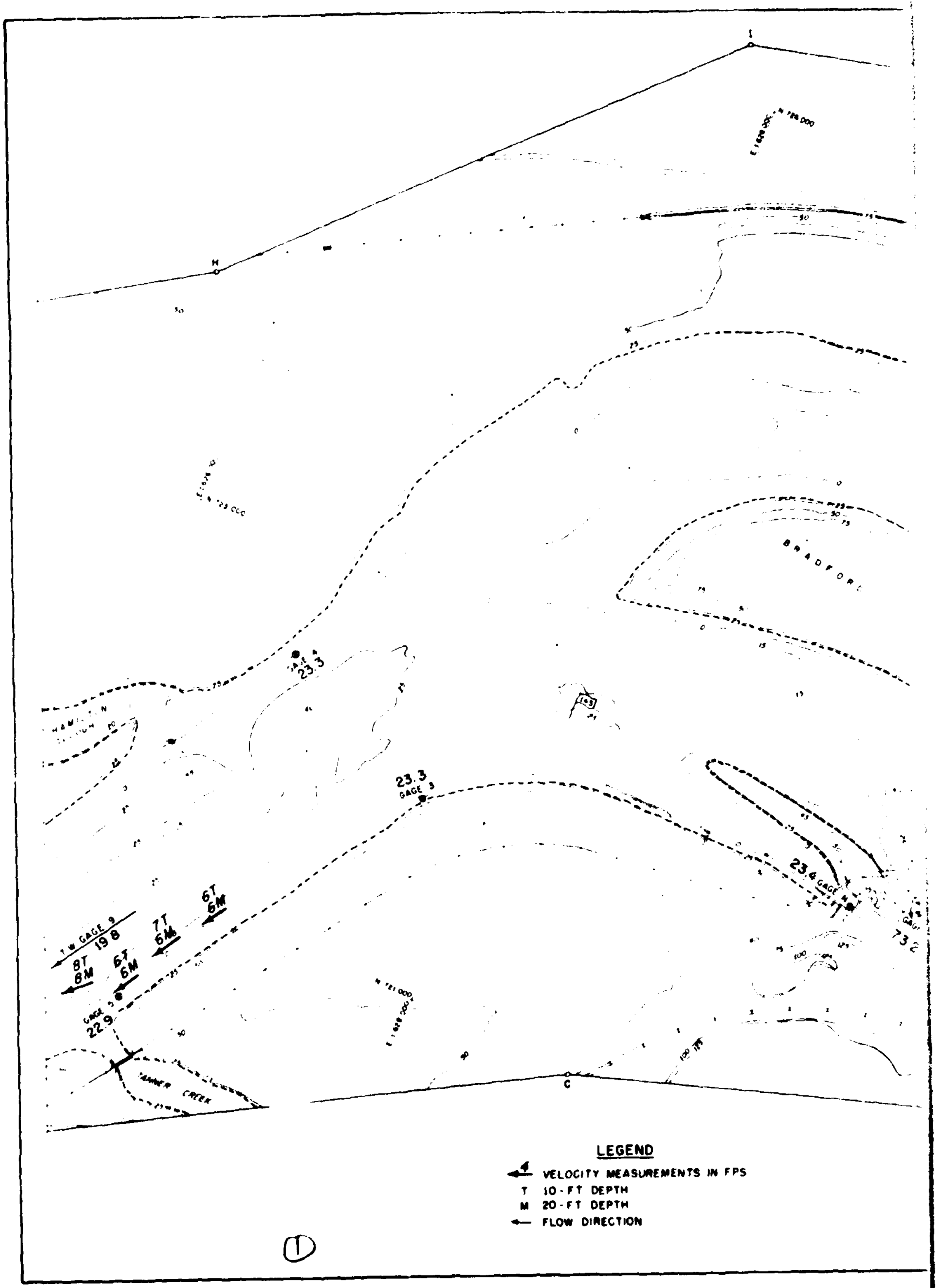
*INCLUDES FISHWAY FLOWS

FLOW CONDITIONS

UNIFORM OPERATION OF EXISTING STRUCTURES
RIVER DISCHARGE 200 000 CFS

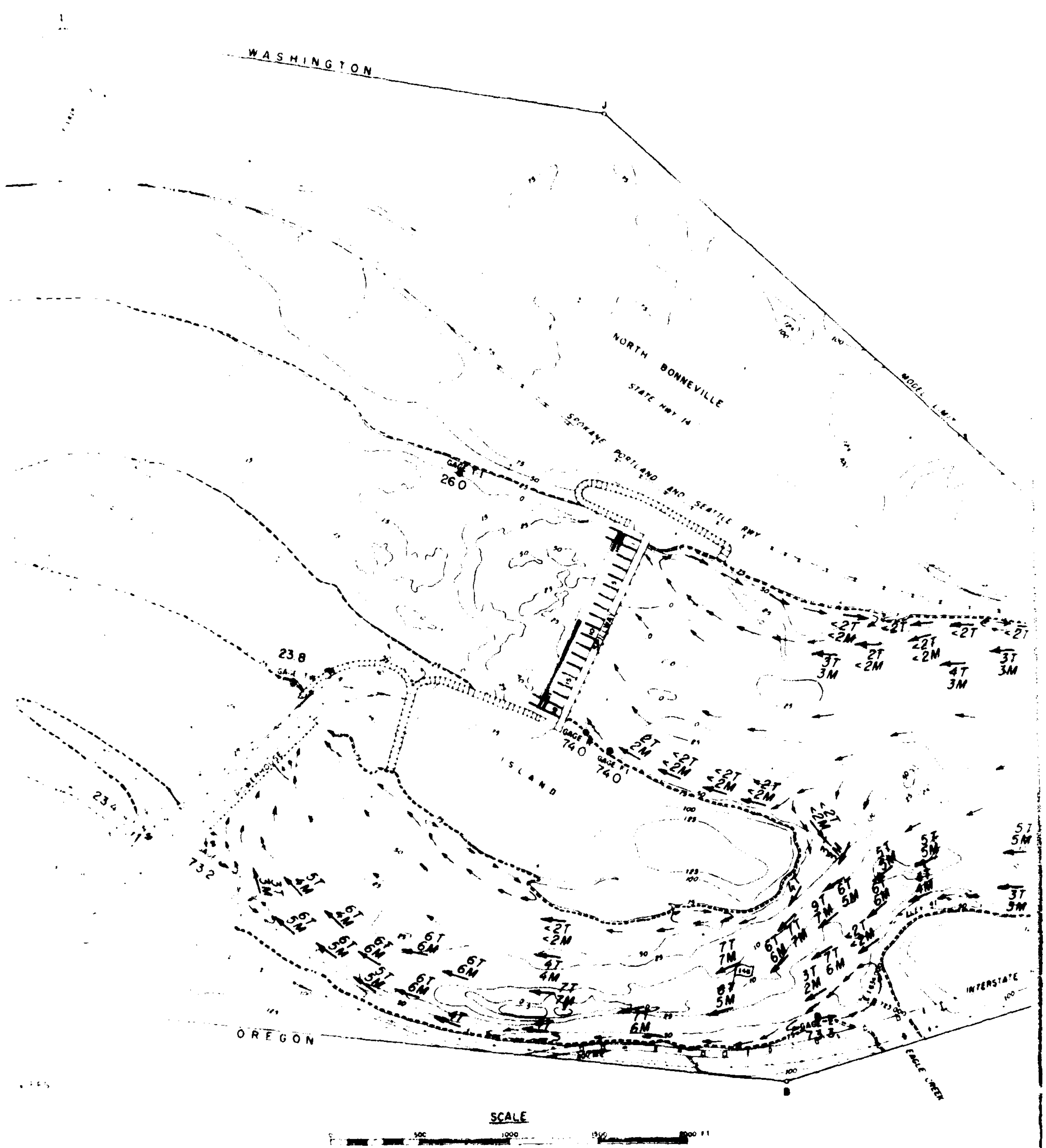
(3 of 3)

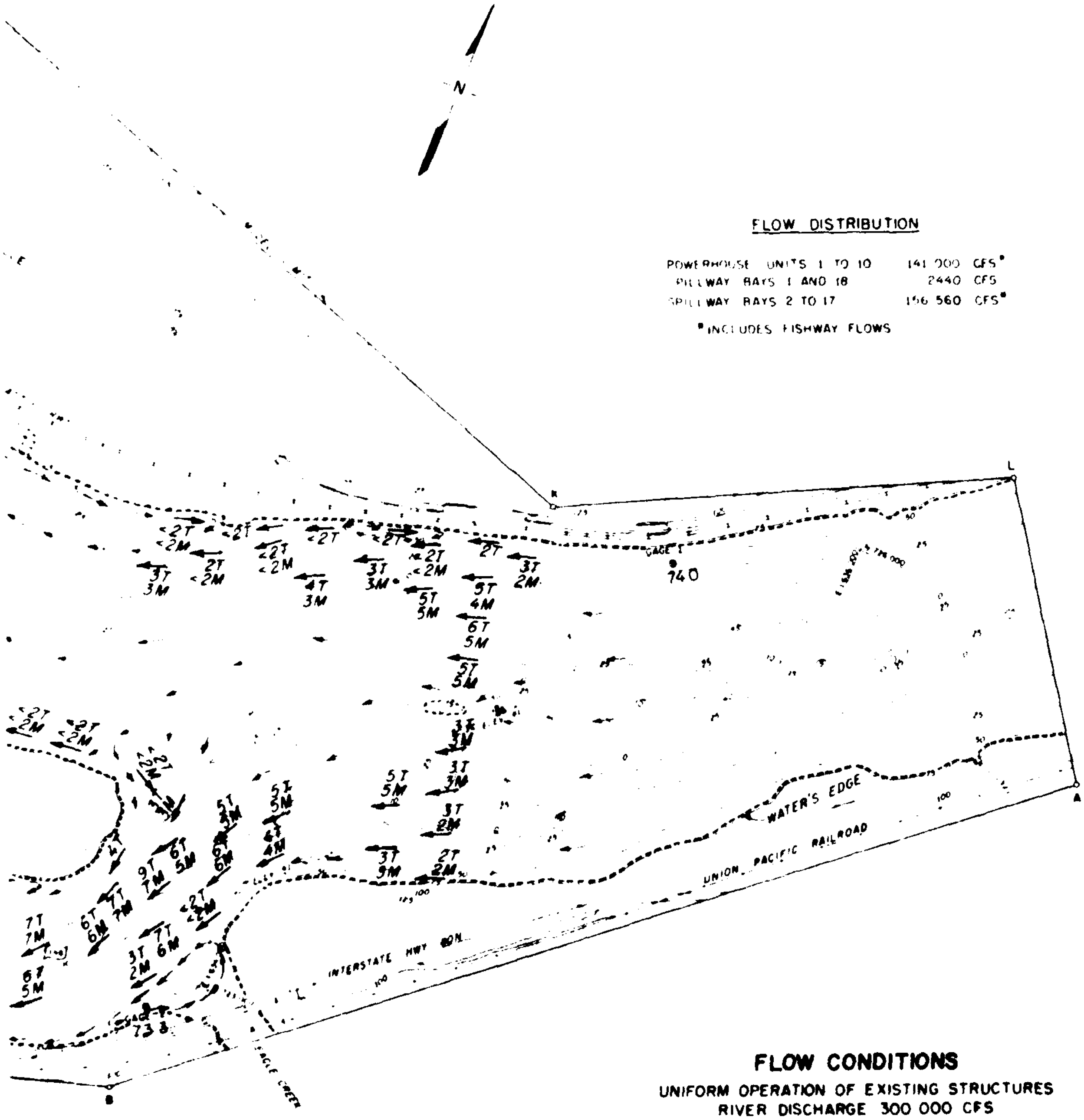
PLATE 7



BRADFORD
23.3
23.3
GAGE 3
23.4
TW GAGE 9
19.8
8T
8M
6T
6M
7T
6M
6T
6M
GAGE 5
22.9
TANNER CREEK
LEGEND
VELOCITY MEASUREMENTS IN FPS
T 10-FT DEPTH
M 20-FT DEPTH
FLOW DIRECTION

PLATE 8


WASHINGTON
NORTH BONNEVILLE
STATE HWY 14
SPOKANE PORTLAND AND SEATTLE RWY
ISLAND
OREGON
INTERSTATE
EAGLE CREEK
SCALE
0
500
1000
1500
2000 FT



FLOW DISTRIBUTION

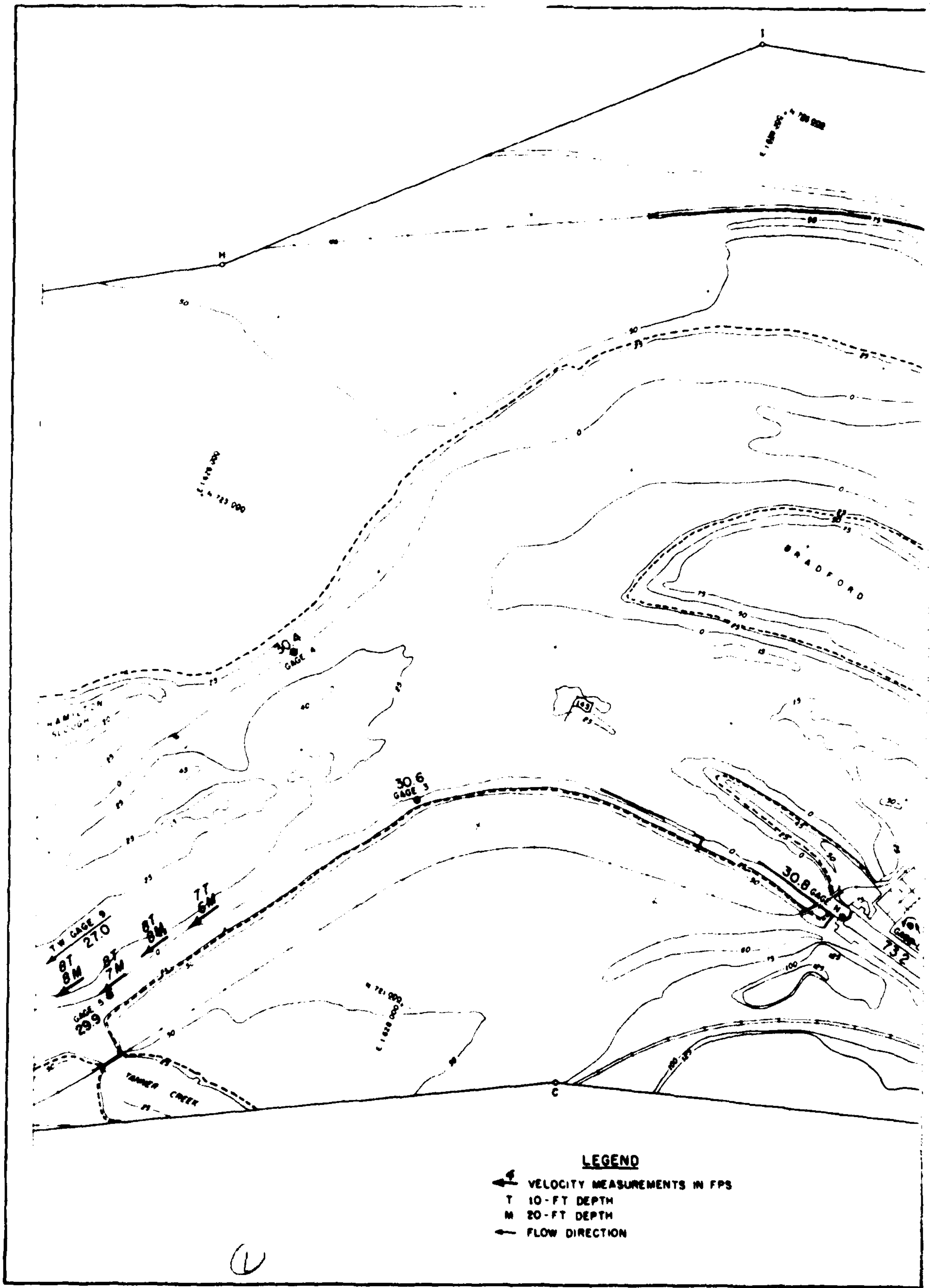
POWERHOUSE UNITS 1 TO 10	141 000 CFS*
SPILLWAY BAYS 1 AND 18	2440 CFS
SPILLWAY BAYS 2 TO 17	156 560 CFS*

*INCLUDES FISHWAY FLOWS

FLOW CONDITIONS

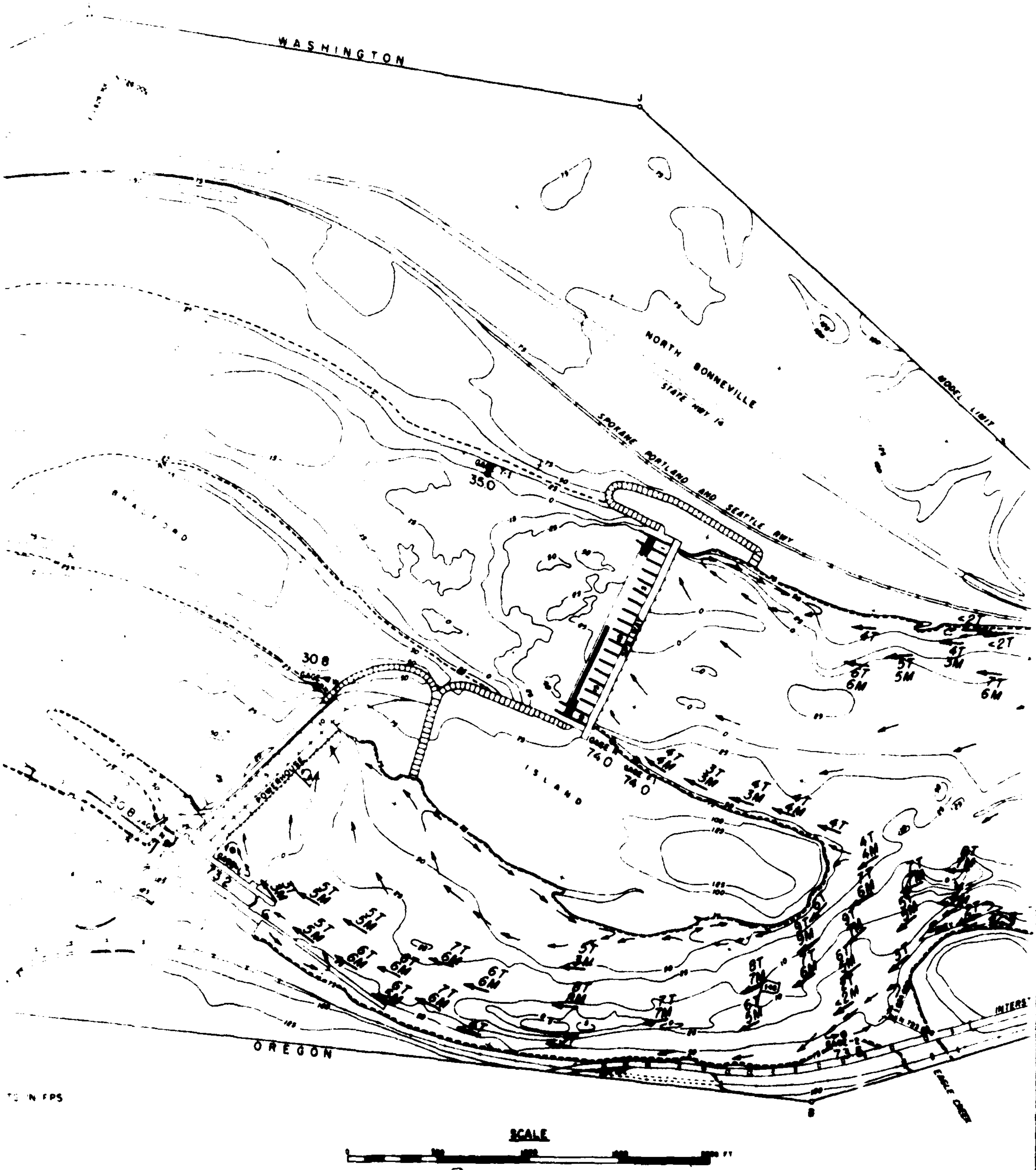
UNIFORM OPERATION OF EXISTING STRUCTURES
RIVER DISCHARGE 300 000 CFS

3 of 3

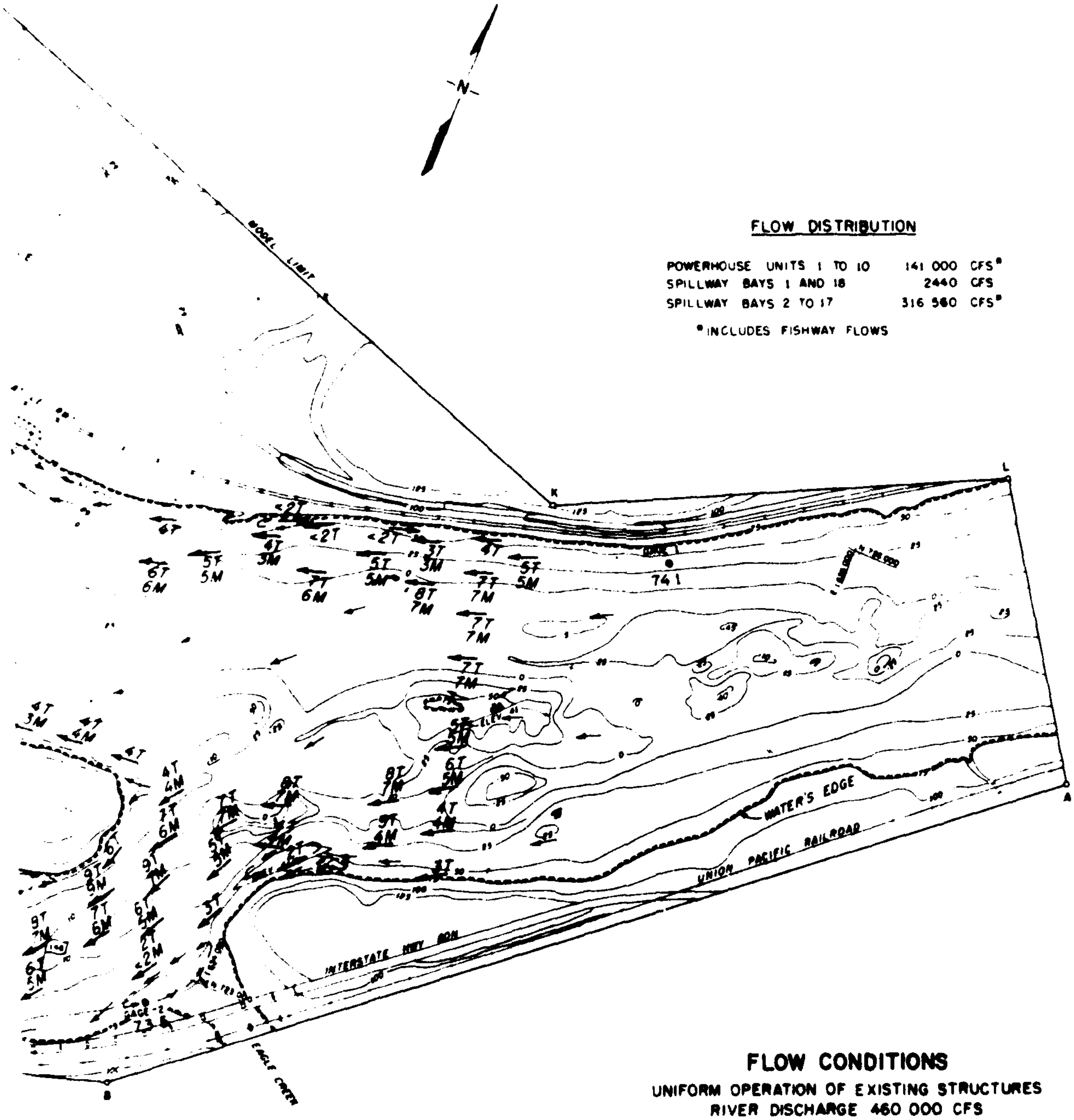


BRADFORD
30.4
GAGE 4
30.6
GAGE 3
30.8
732
TW GAGE 9
27.0
8T
8M
8T
7M
8T
8M
7T
6M
GAGE 5
29.9
TANNER CREEK
LEGEND
VELOCITY MEASUREMENTS IN FPS
T 10-FT DEPTH
M 20-FT DEPTH
FLOW DIRECTION

PLATE 9


WASHINGTON
NORTH BONNEVILLE
STATE HWY 14
SPOKANE PORTLAND AND SEATTLE RWY
MODEL LIMIT
ISLAND
POWERHOUSE
OREGON
EAGLE CREEK
SCALE

(2)



FLOW CONDITIONS
UNIFORM OPERATION OF EXISTING STRUCTURES
RIVER DISCHARGE 460 000 CFS

(3 of 3)

PLATE 9

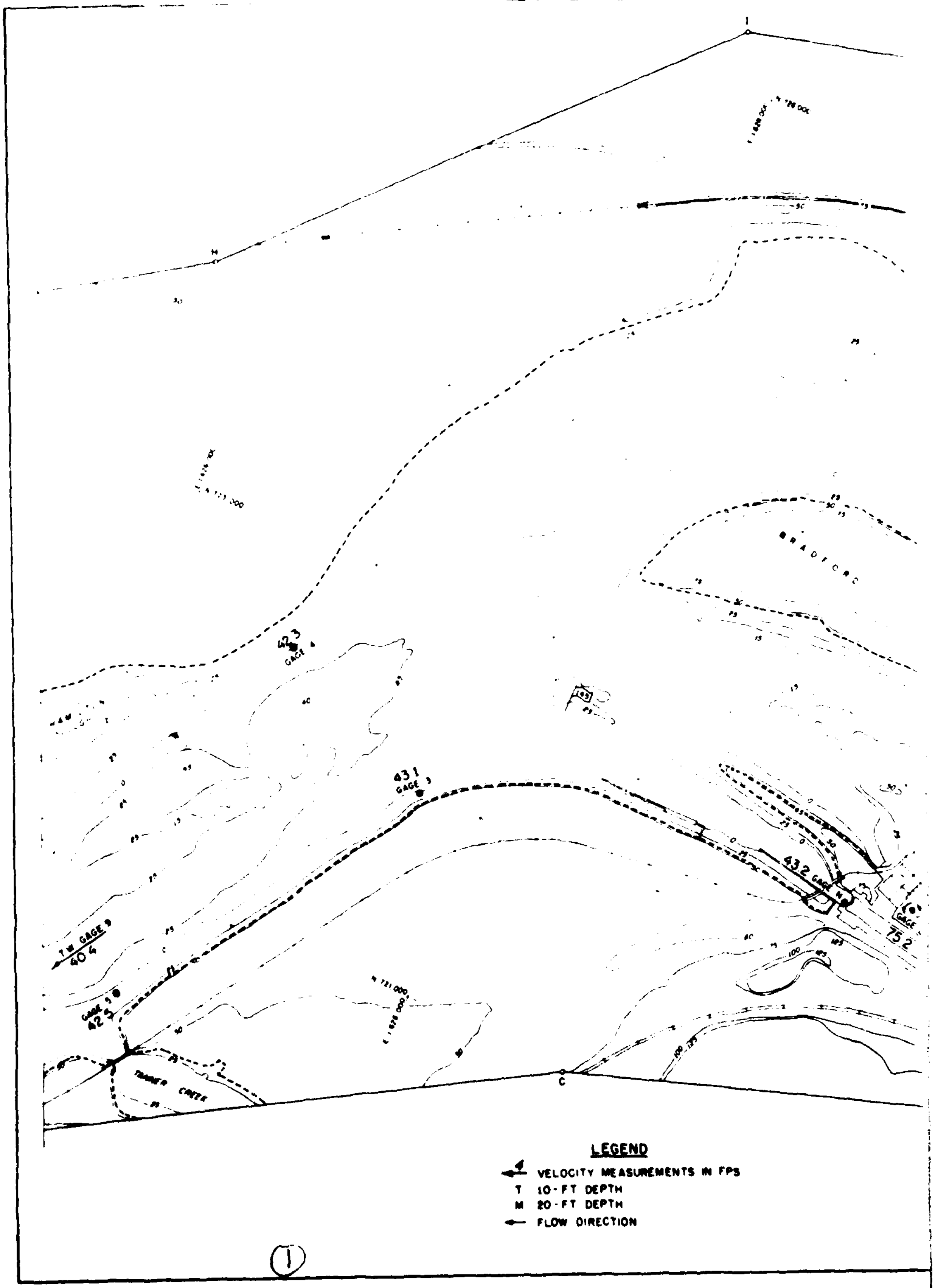
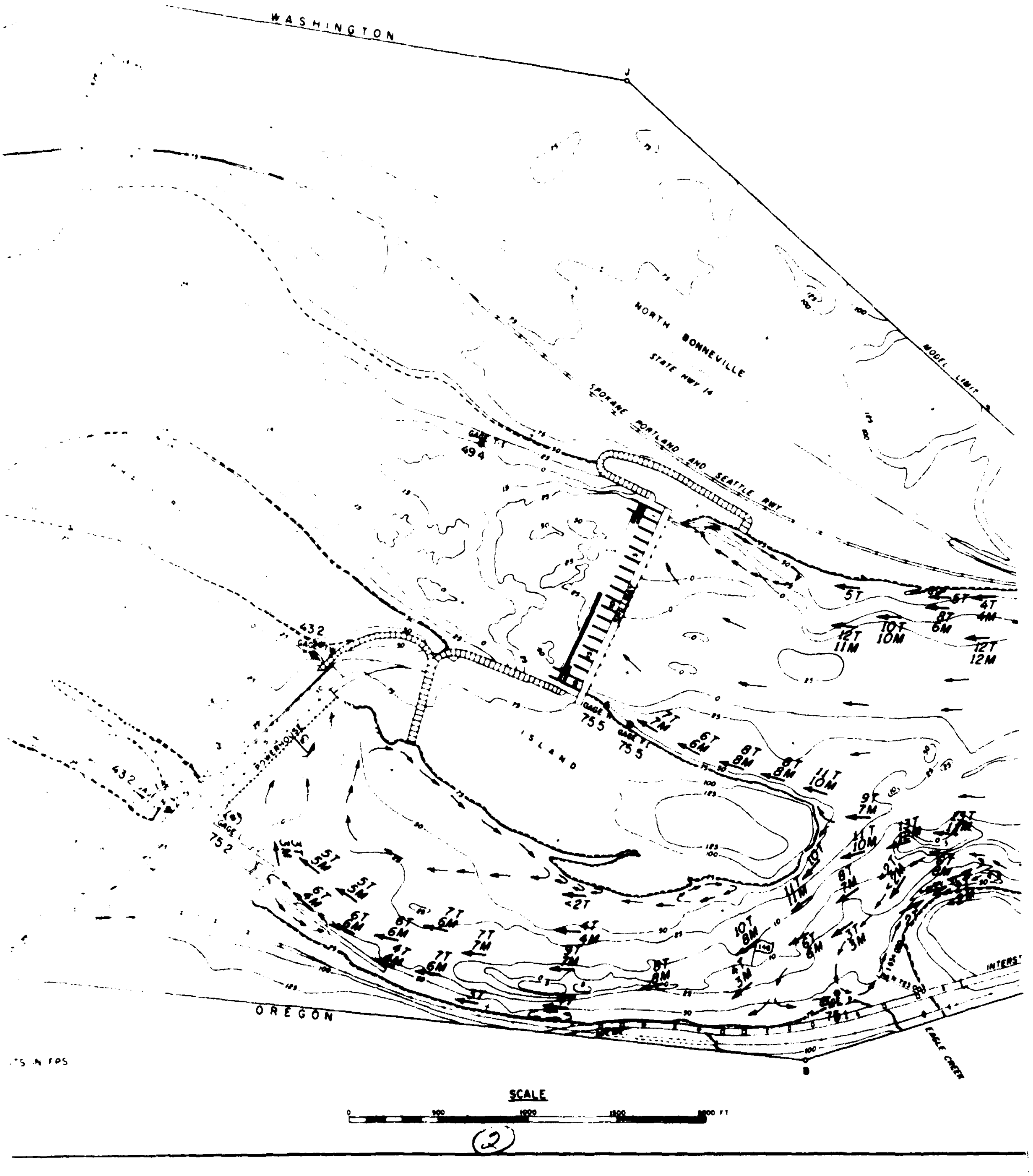
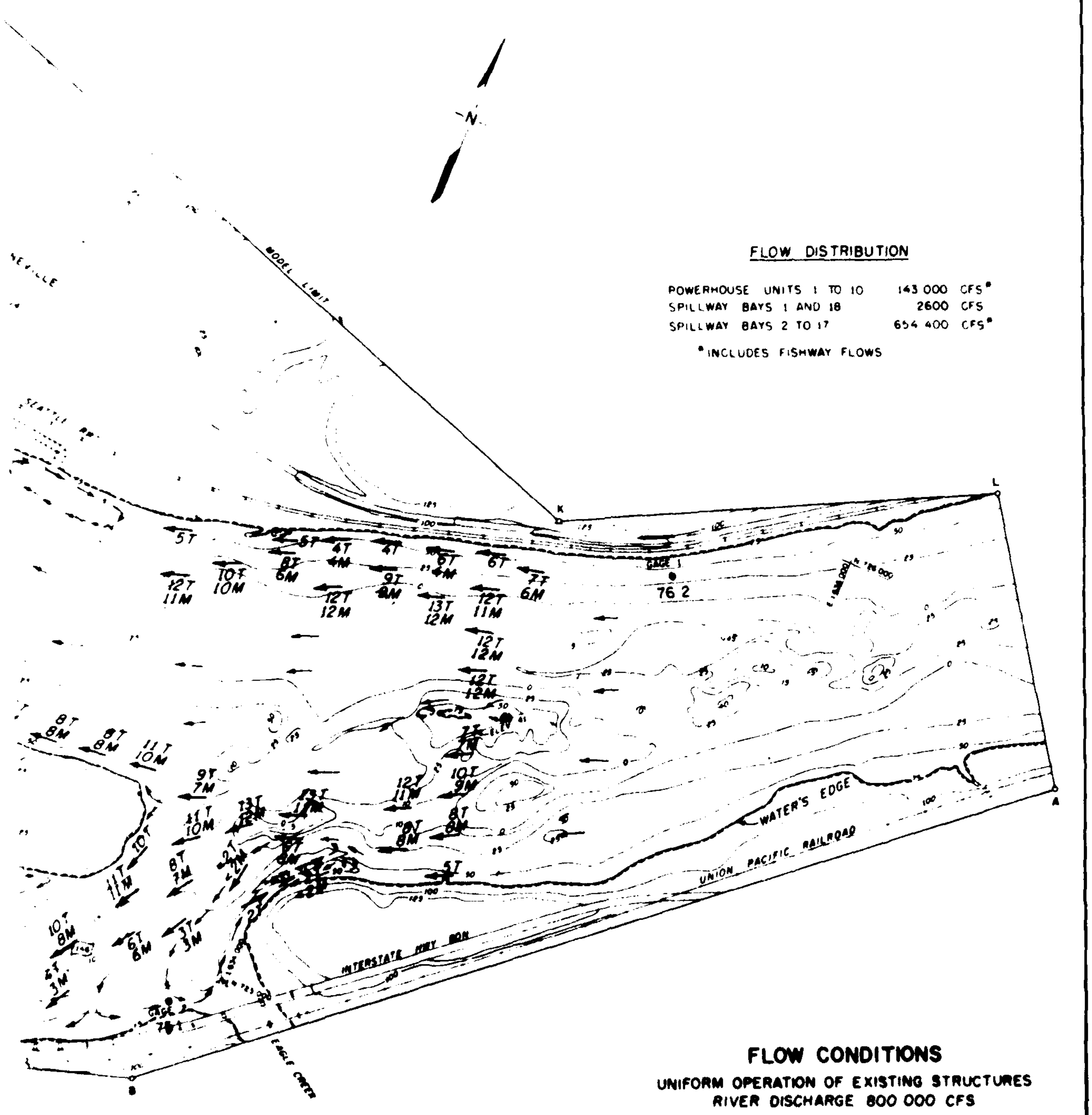

BRADFORD
431
GAGE 3
432 GAGE
423
GAGE 4
TW GAGE 9
40 4
GAGE 2
42 3
TANNER CREEK
75 2
LEGEND
VELOCITY MEASUREMENTS IN FPS
T 10-FT DEPTH
M 20-FT DEPTH
FLOW DIRECTION
1

PLATE 10


WASHINGTON
NORTH BONNEVILLE
STATE HWY 14
SPOKANE PORTLAND AND SEATTLE RWY
MODEL LIMIT
ISLAND
POWERHOUSE
OREGON
EAGLE CREEK
SCALE
0
500
1000
1500
2000 FT

(2)



FLOW DISTRIBUTION

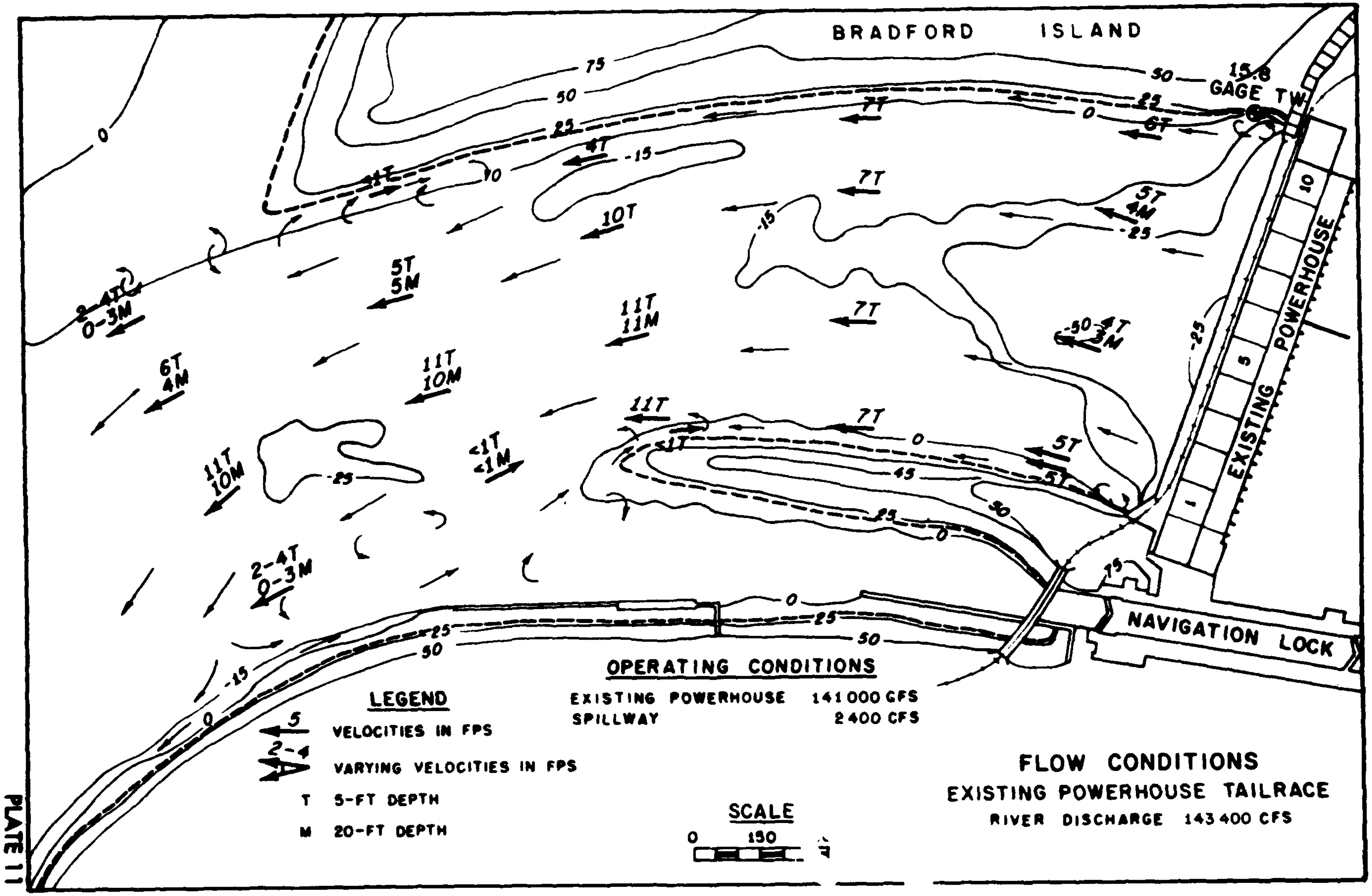
POWERHOUSE UNITS 1 TO 10	143 000 CFS*
SPILLWAY BAYS 1 AND 18	2600 CFS
SPILLWAY BAYS 2 TO 17	654 400 CFS*

*INCLUDES FISHWAY FLOWS

FLOW CONDITIONS

UNIFORM OPERATION OF EXISTING STRUCTURES
RIVER DISCHARGE 800 000 CFS

(3)



FLOW CONDITIONS
EXISTING POWERHOUSE TAILRACE
RIVER DISCHARGE 143 400 CFS

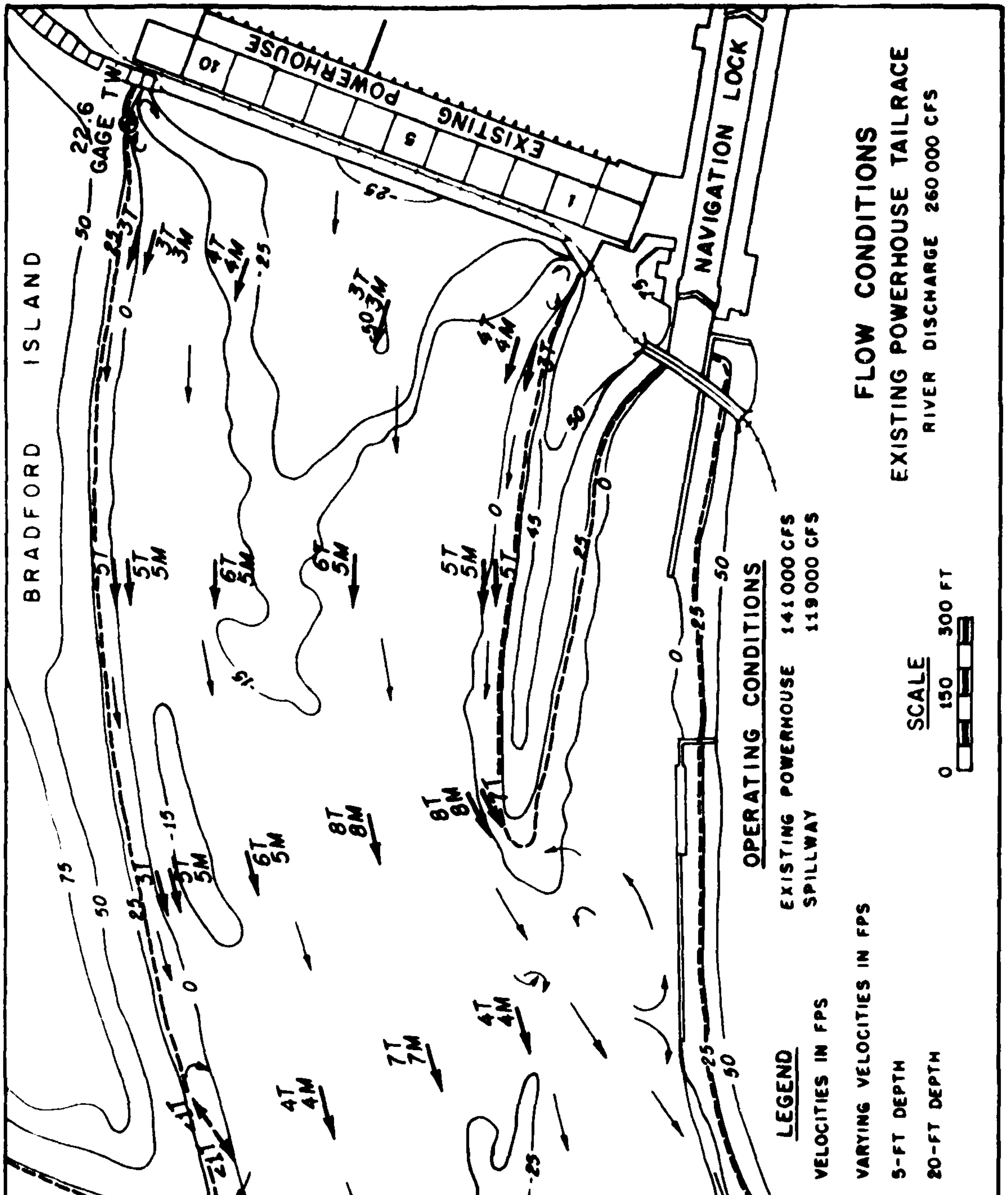
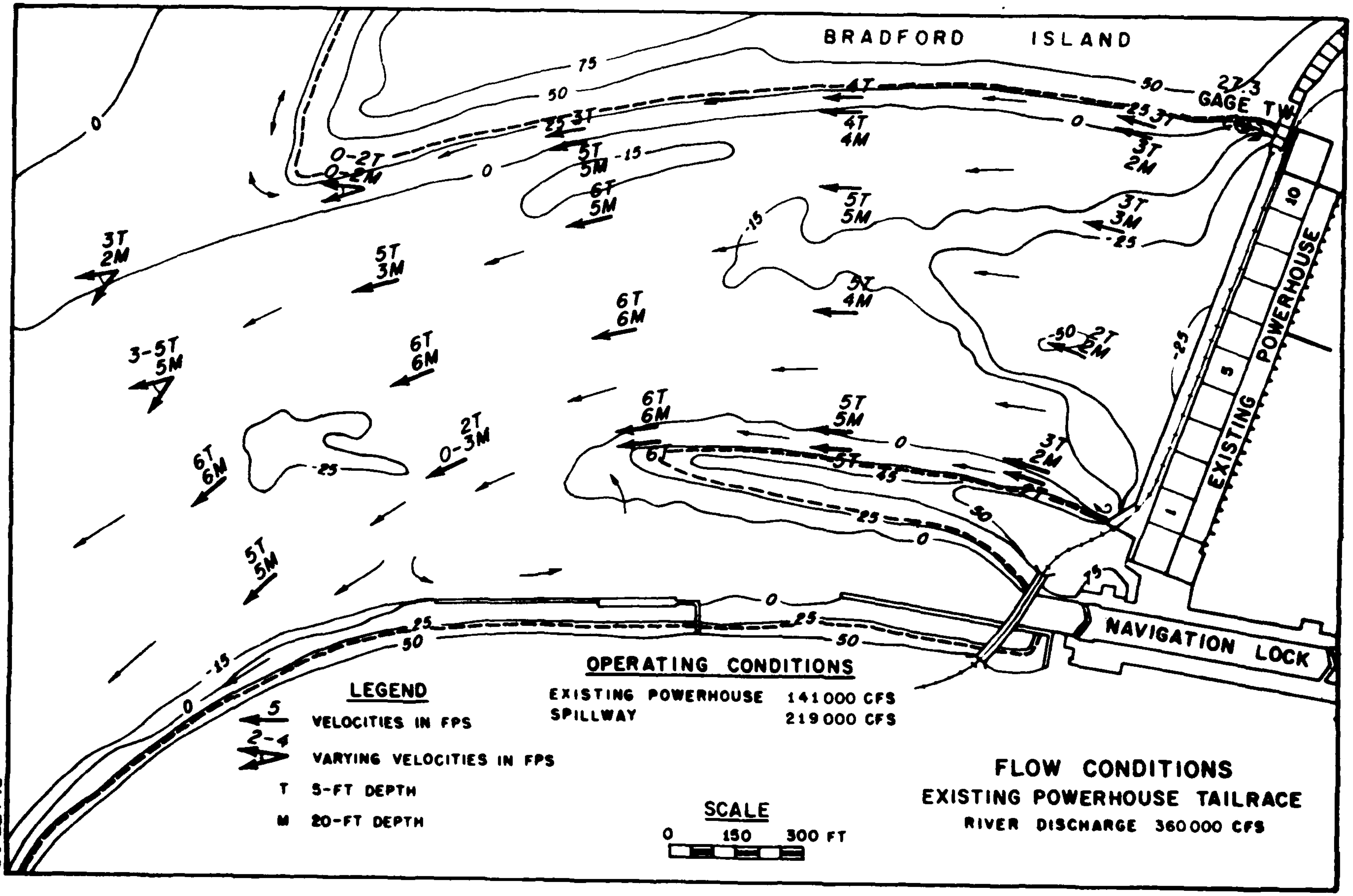
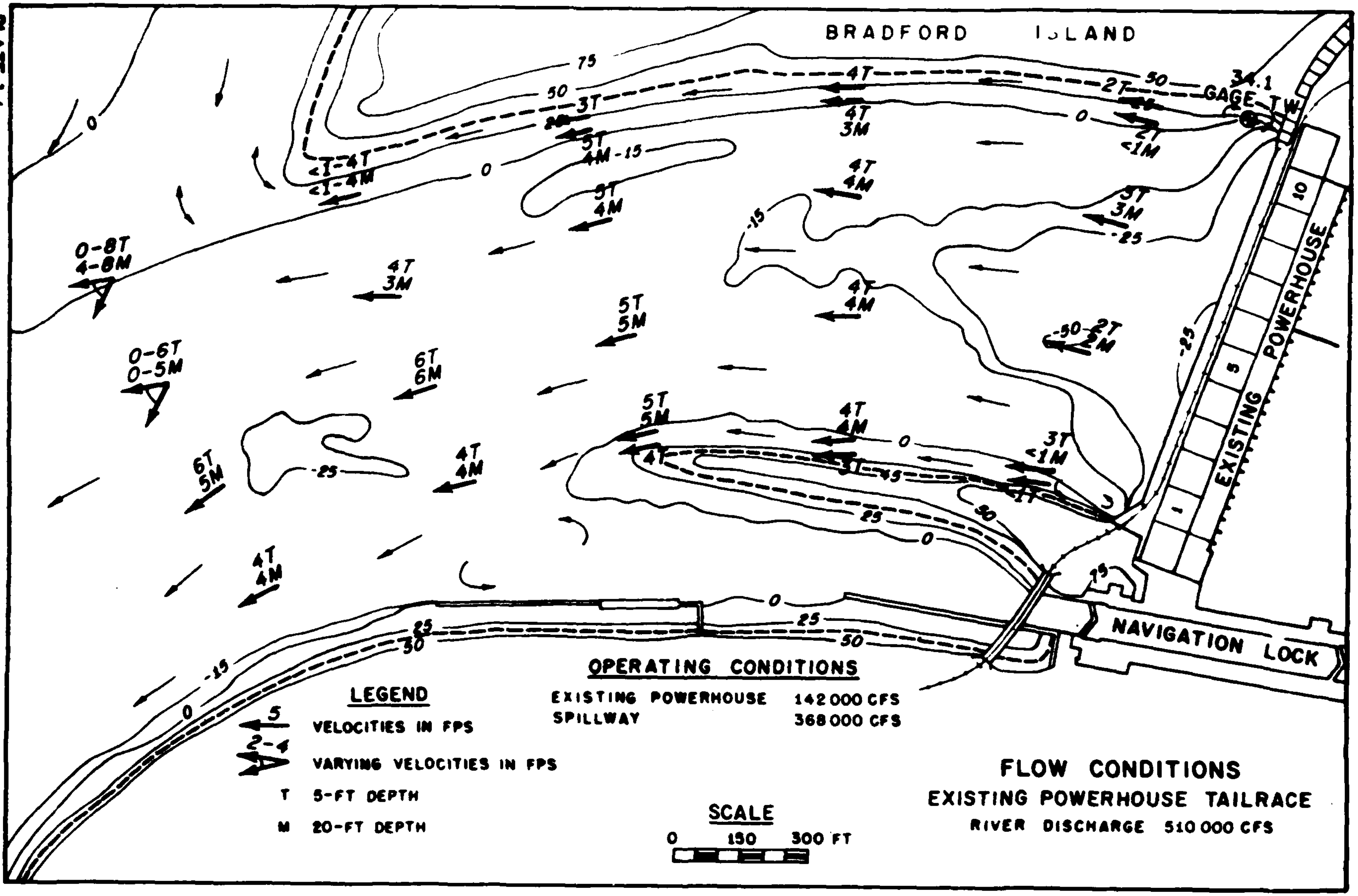

FLOW CONDITIONS
EXISTING POWERHOUSE TAILRACE
RIVER DISCHARGE 260 000 CFS
OPERATING CONDITIONS
EXISTING POWERHOUSE 141 000 CFS
SPILLWAY 119 000 CFS
SCALE
0 150 300 FT
LEGEND
VELOCITIES IN FPS
VARYING VELOCITIES IN FPS
T 5-FT DEPTH
M 20-FT DEPTH
BRADFORD ISLAND
EXISTING POWERHOUSE
NAVIGATION LOCK
22.6
GAGE TW

PLATE 12



FLOW CONDITIONS
EXISTING POWERHOUSE TAILRACE
RIVER DISCHARGE 360 000 CFS

PLATE 13



FLOW CONDITIONS
EXISTING POWERHOUSE TAILRACE
RIVER DISCHARGE 510 000 CFS

PLATE 14

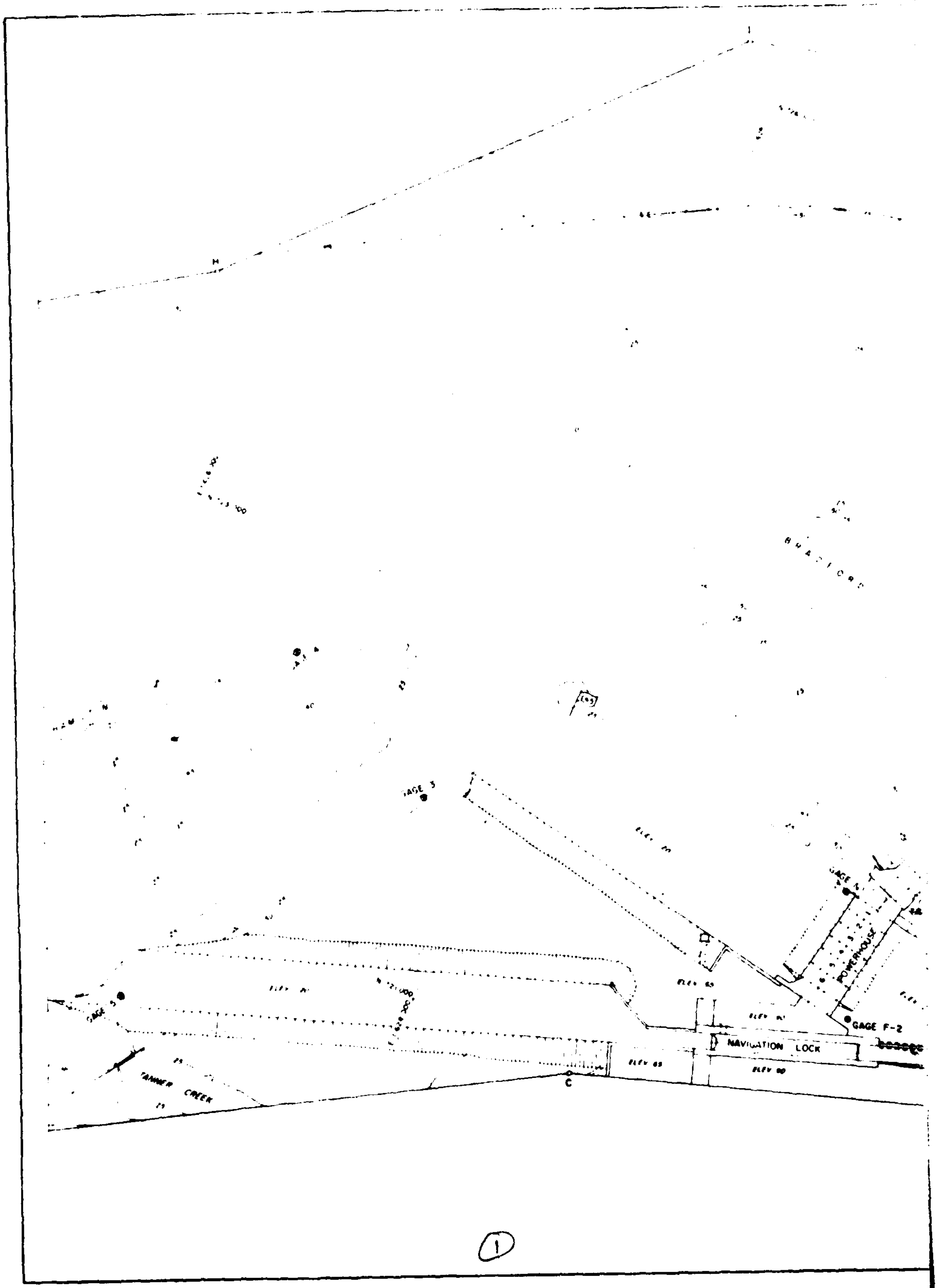
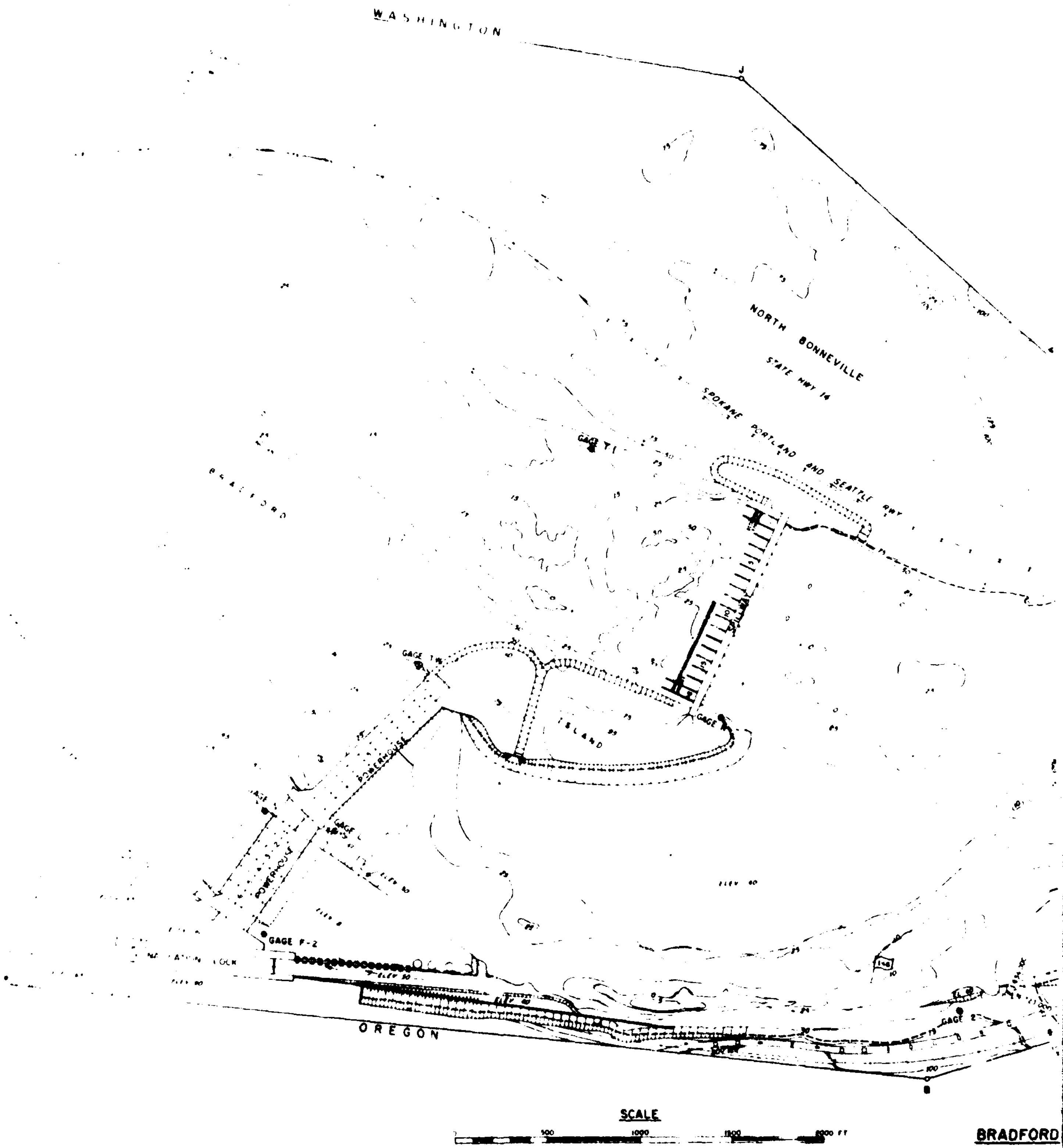
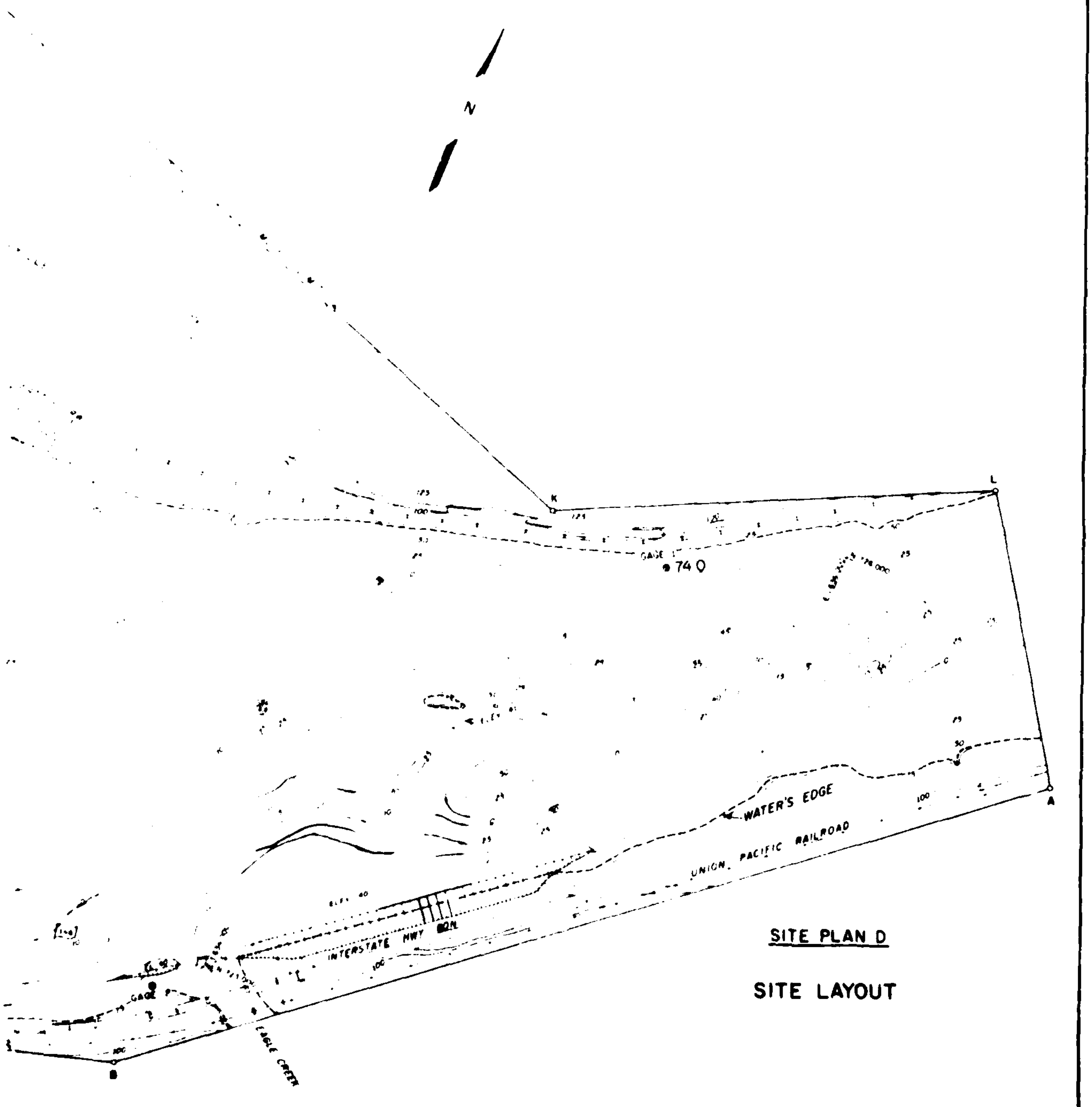

BRADFORD
GAGE 5
GAGE 4
POWERHOUSE
GAGE F-2
NAVIGATION LOCK
TANNER CREEK
C
1

PLATE 15



BRADFORD
EAGLE

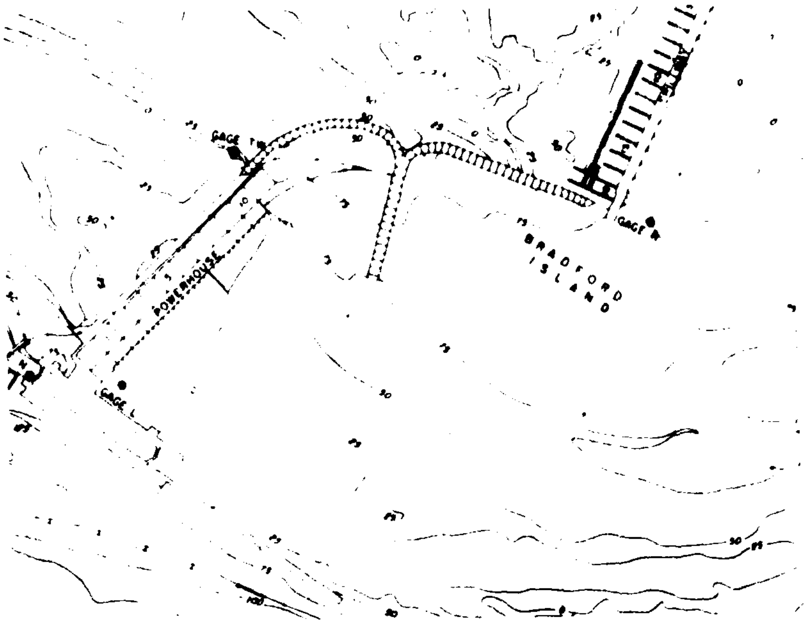
(2)



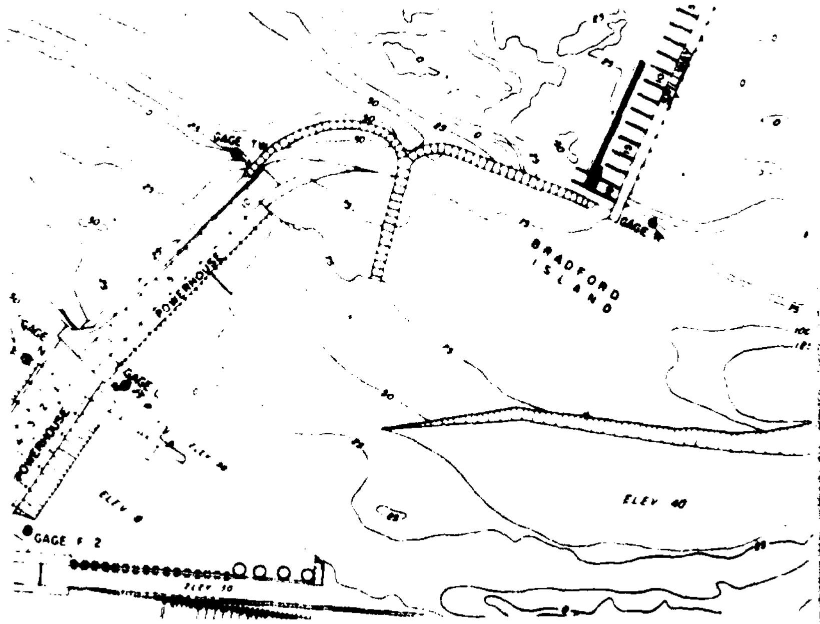
BRADFORD ISLAND PLAN 3 EXCAVATION
EAGLE CREEK PLAN 1 EXCAVATION

3 of 3

PLATE 15



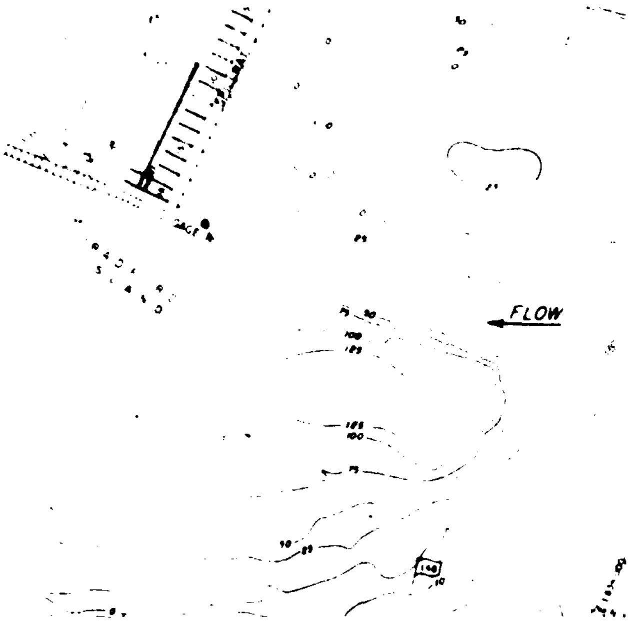
EXISTING CONDITION



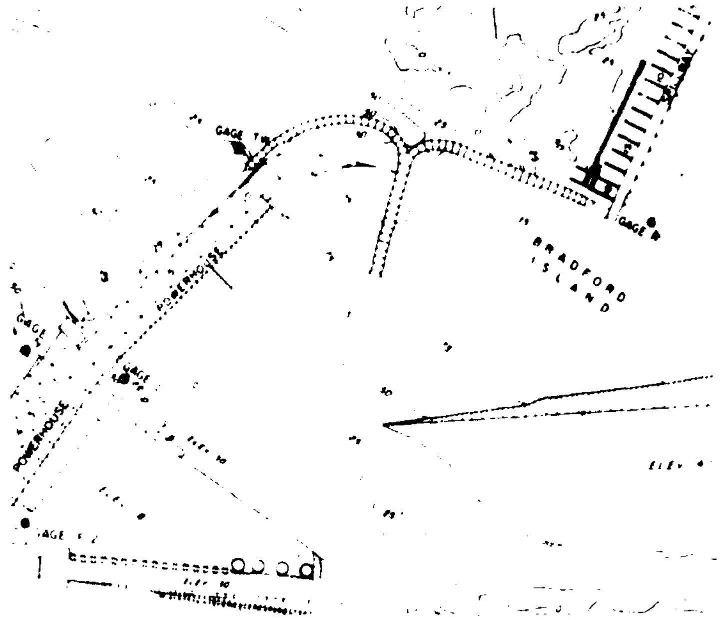
PLAN 2

(1)

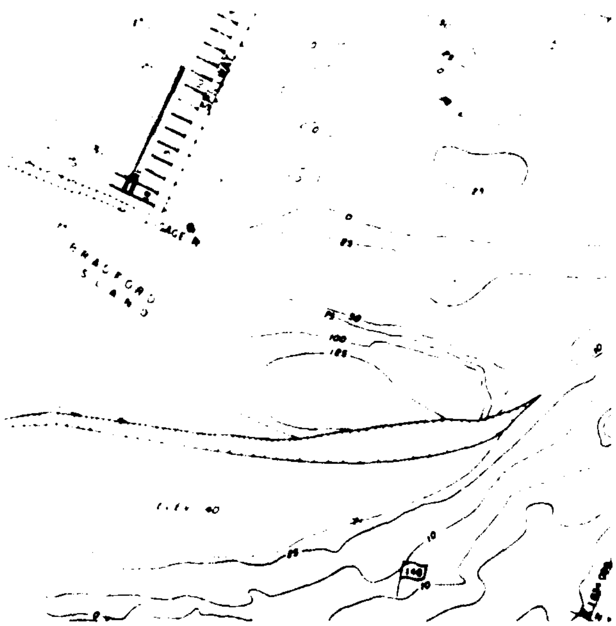
PLAT 16



ISTING CONDITION



PLAN 1

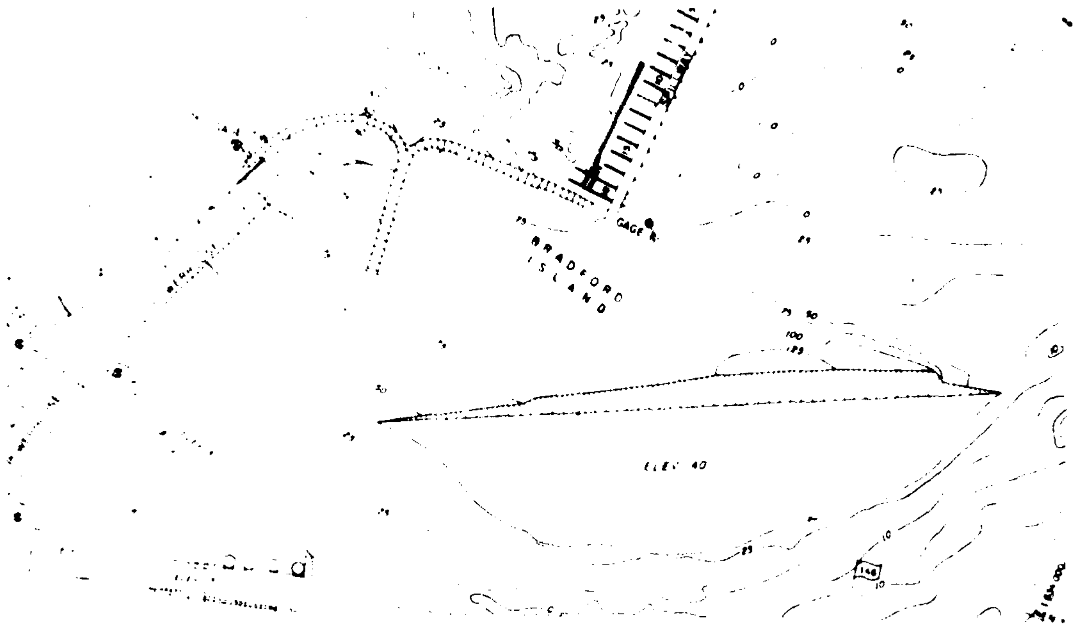


PLAN 2

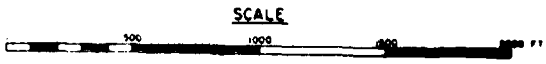
BRAD

EXISTING

2



PLAN 1

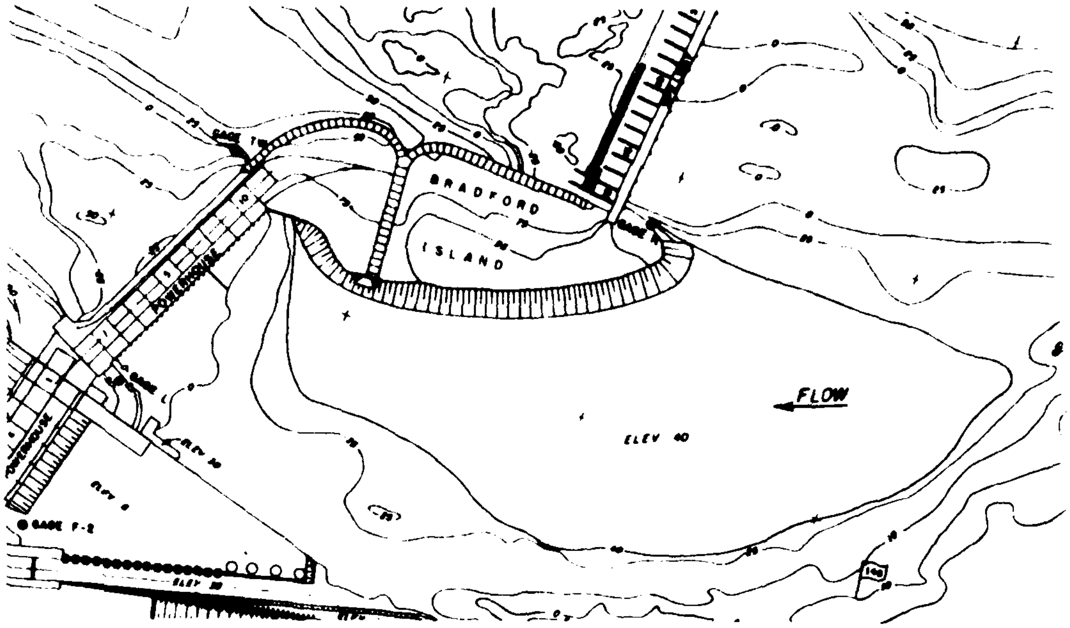


BRADFORD ISLAND EXCAVATION

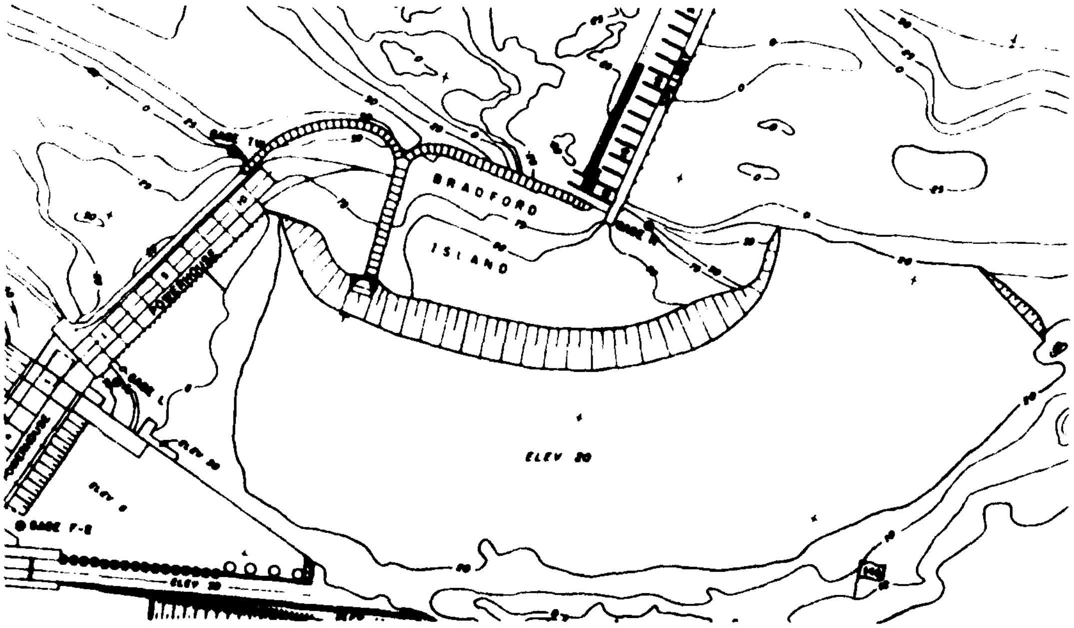
EXISTING CONDITION AND PLANS 1 AND 2

3 of 3

PLATE 16

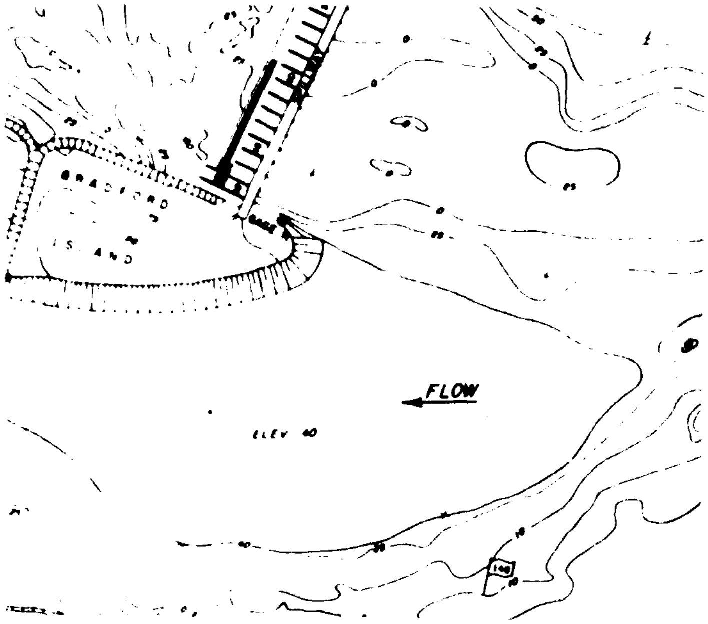


PLAN 3

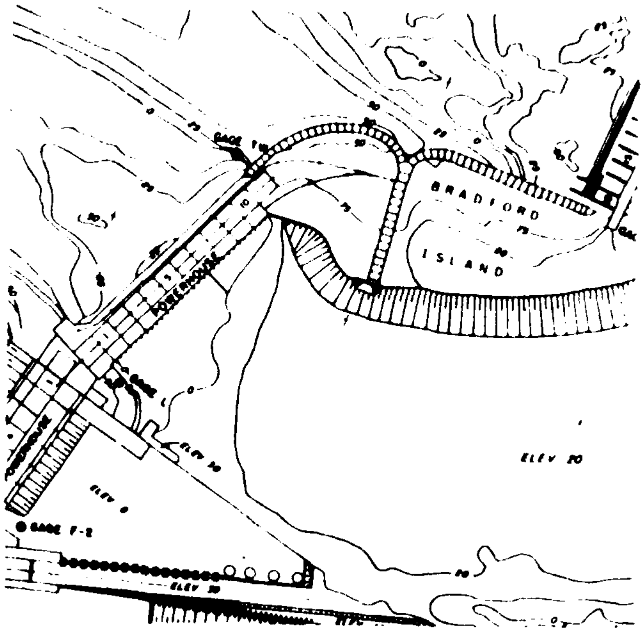


PLAN 5

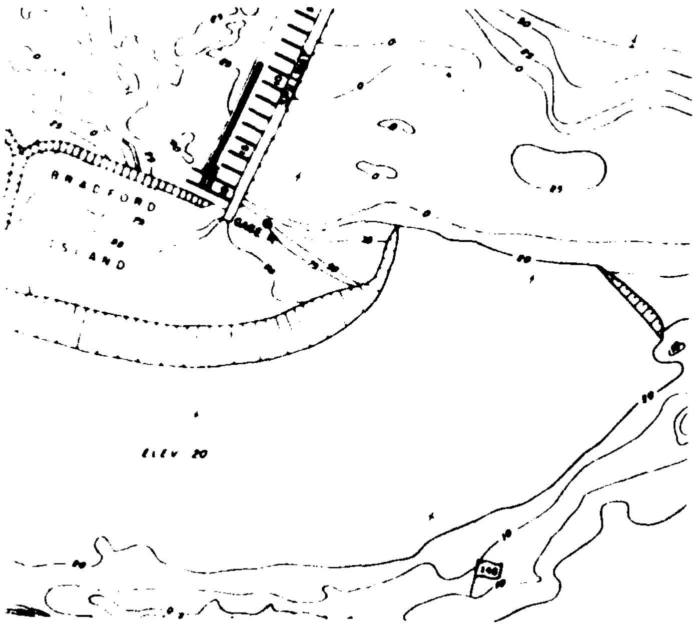
Plate 17



PLAN 3

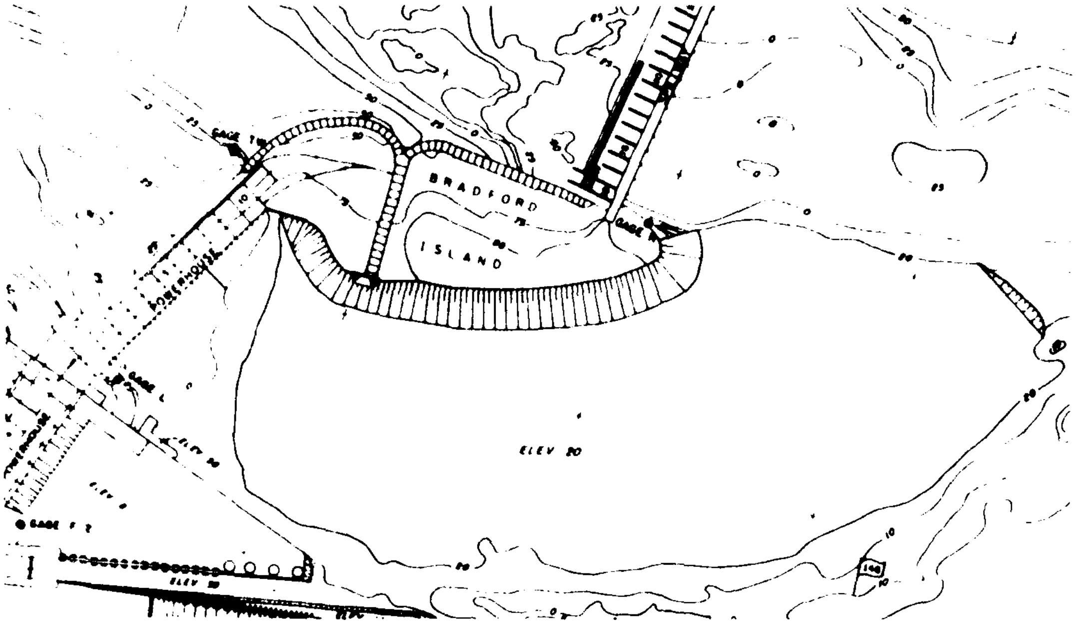


PLAN 4

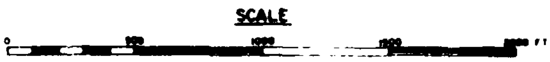


PLAN 5

(2 of 2



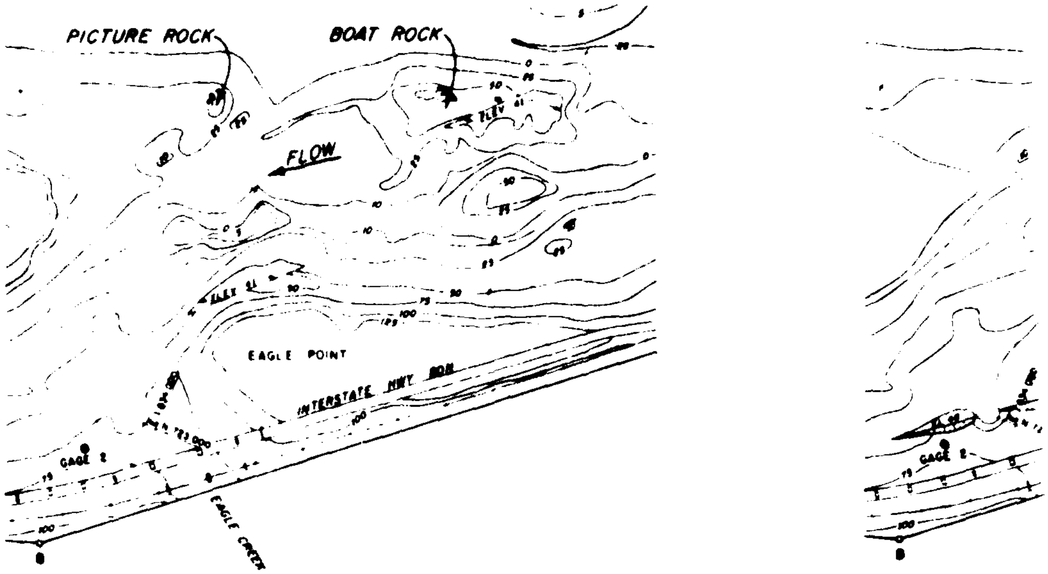
PLAN 4



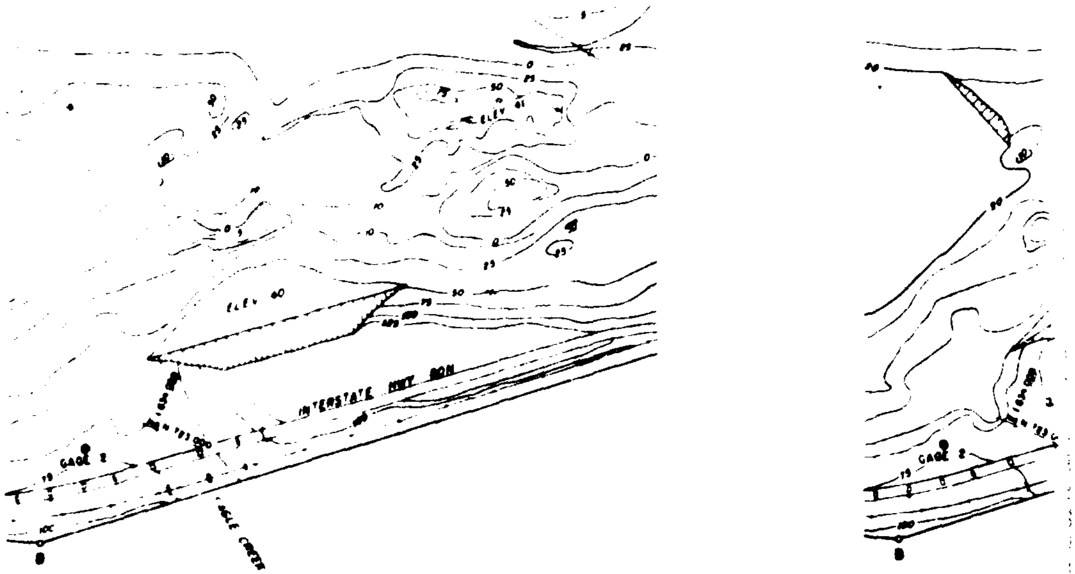
BRADFORD ISLAND EXCAVATION

PLANS 3 TO 5

3 of 3



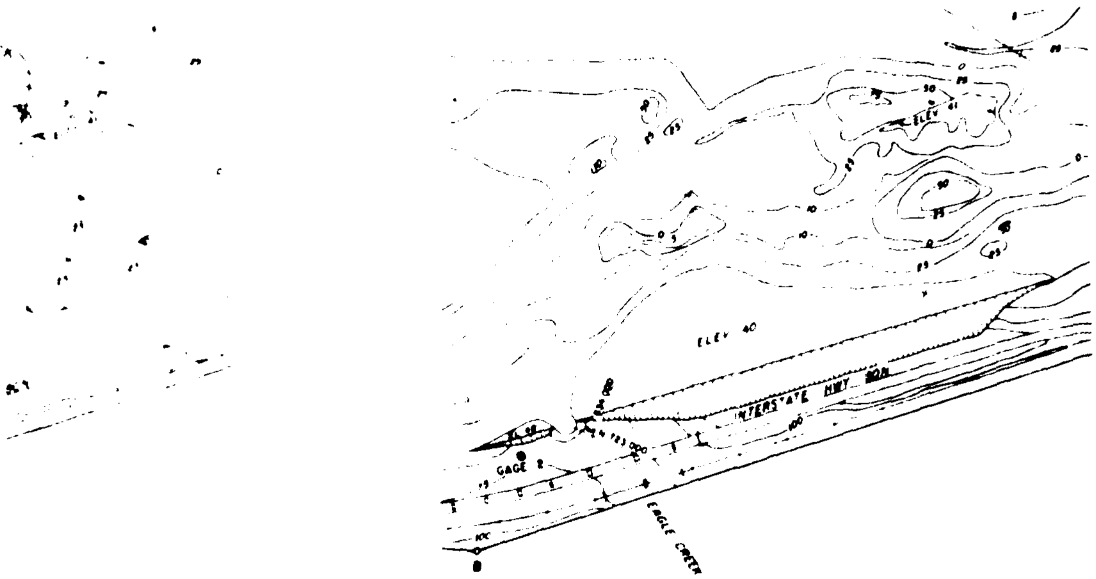
EXISTING CONDITION



PLAN 2

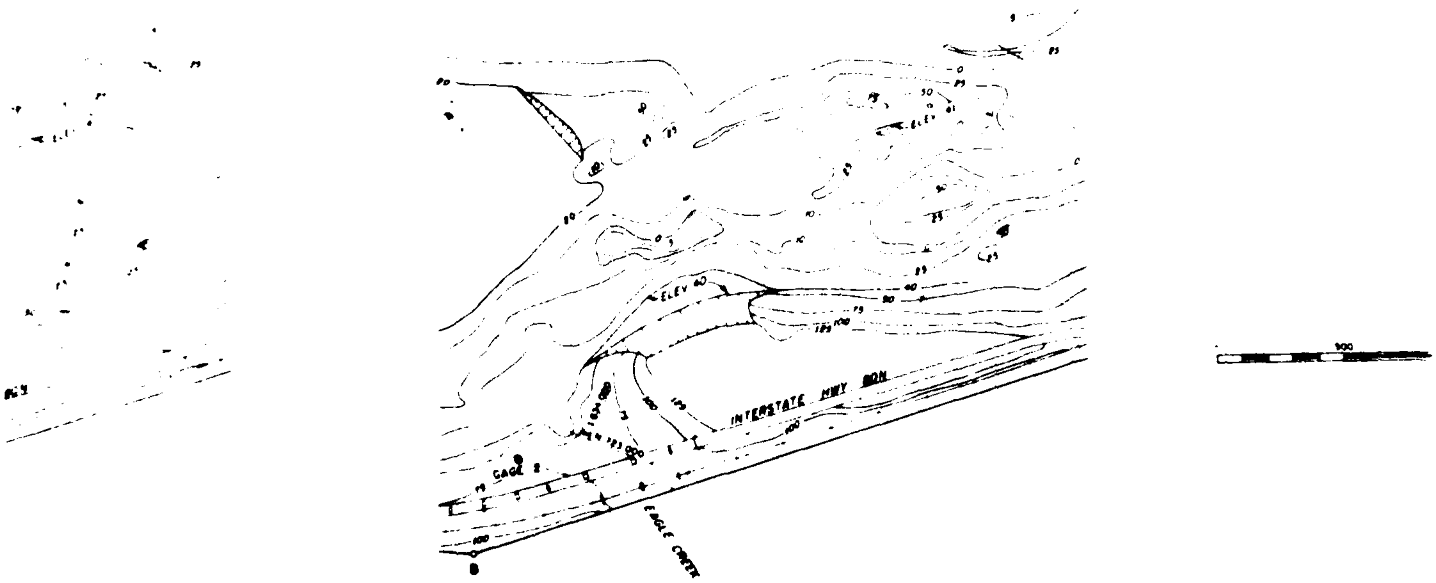
(1)

Plate 15



PLAN 1

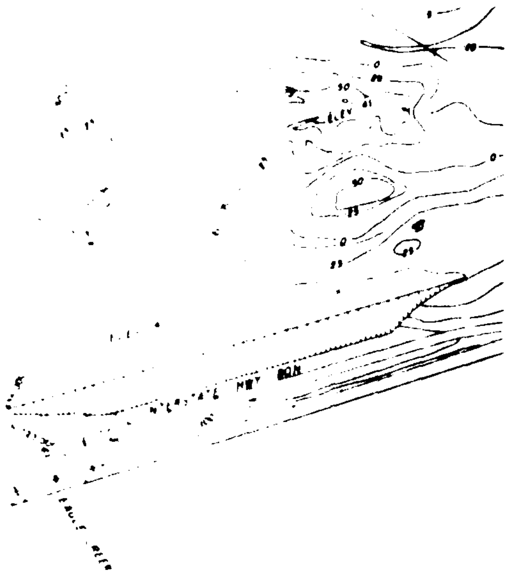
N



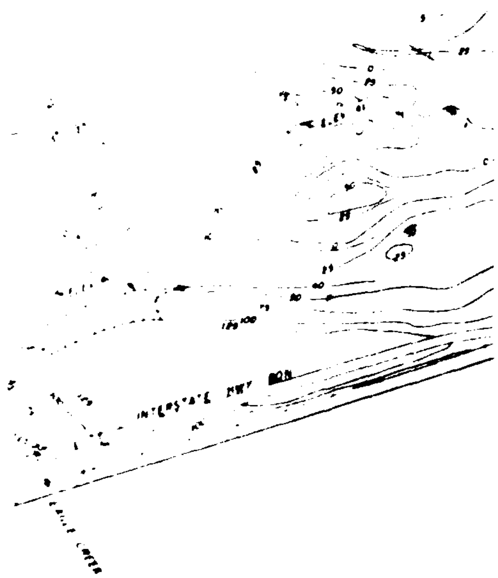
PLAN 3

EAGLE P

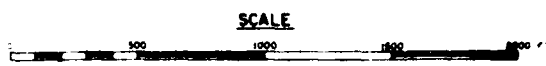
EXISTING COND



PLAN 1



PLAN 3

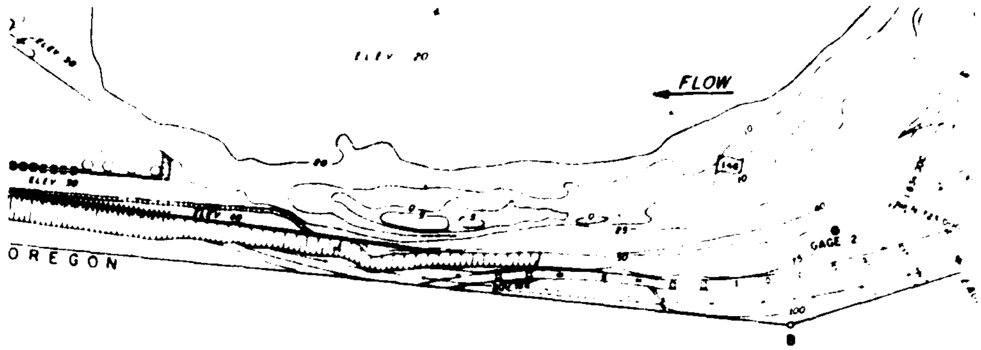


EAGLE POINT EXCAVATION

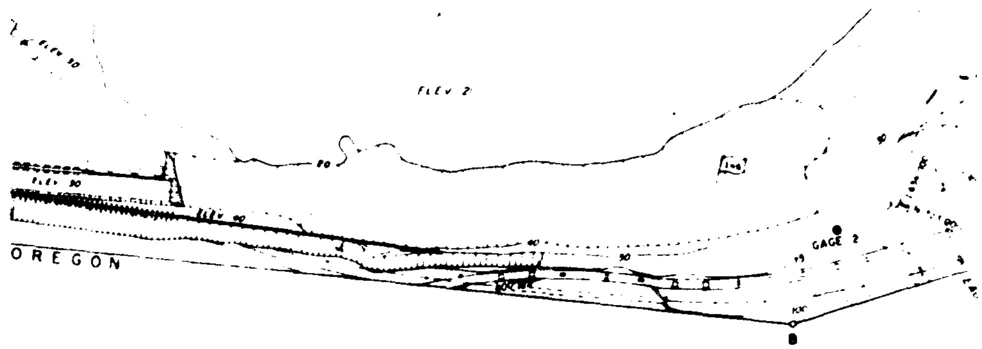
EXISTING CONDITION AND PLANS 1 TO 3

3 of 3

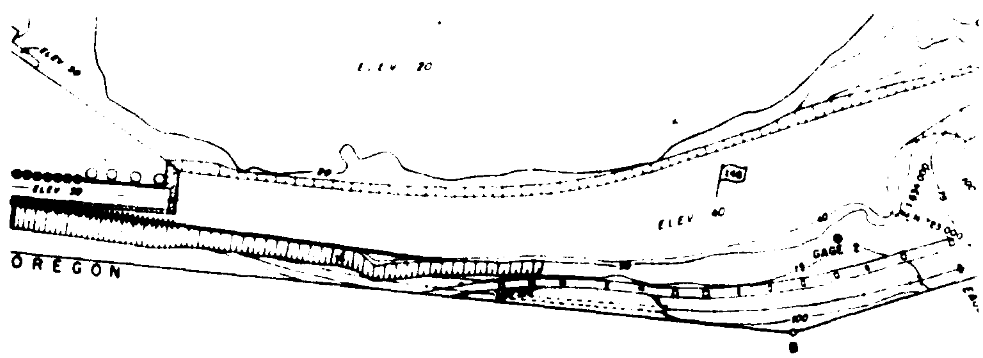
PLATE 18



EXISTING CONDITION



PLAN 2

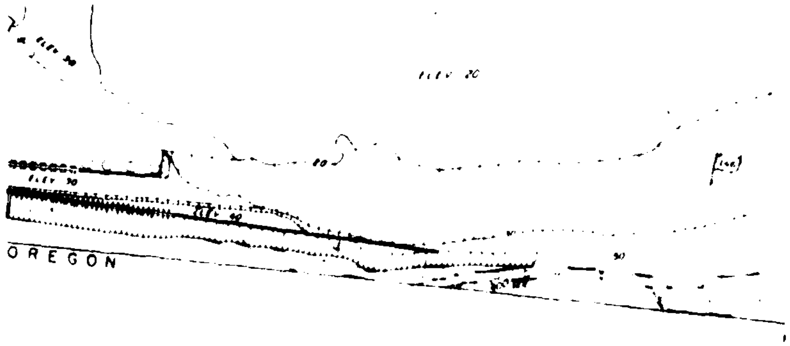


PLAN 4

1

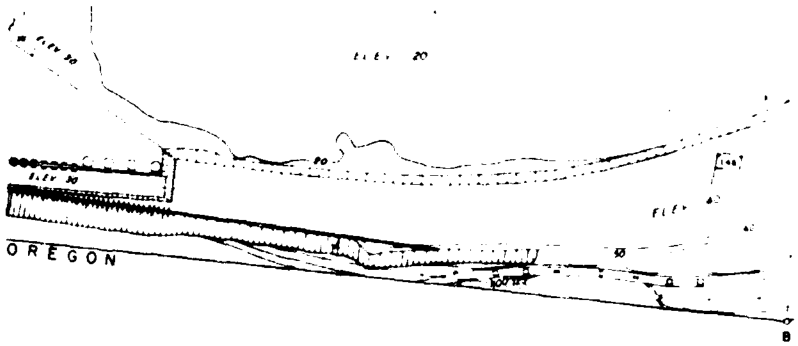
Plate 19

CONDITION



PLAN 1

2

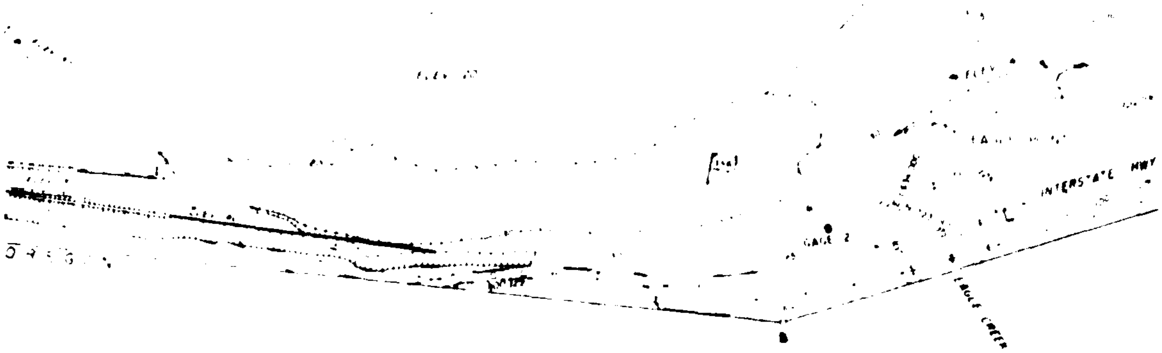


PLAN 3

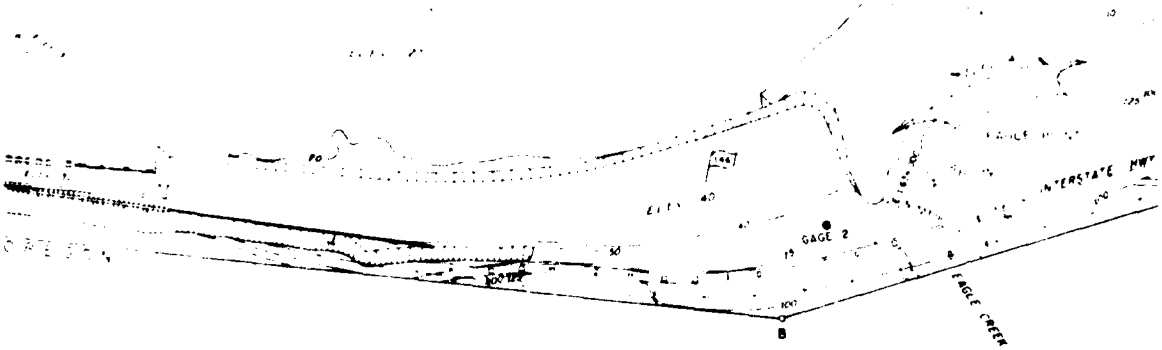
4

SITE D
UPSTREAM A
EXISTING CON

2 of 2

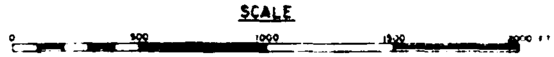


PLAN 1



PLAN 3

SCALE

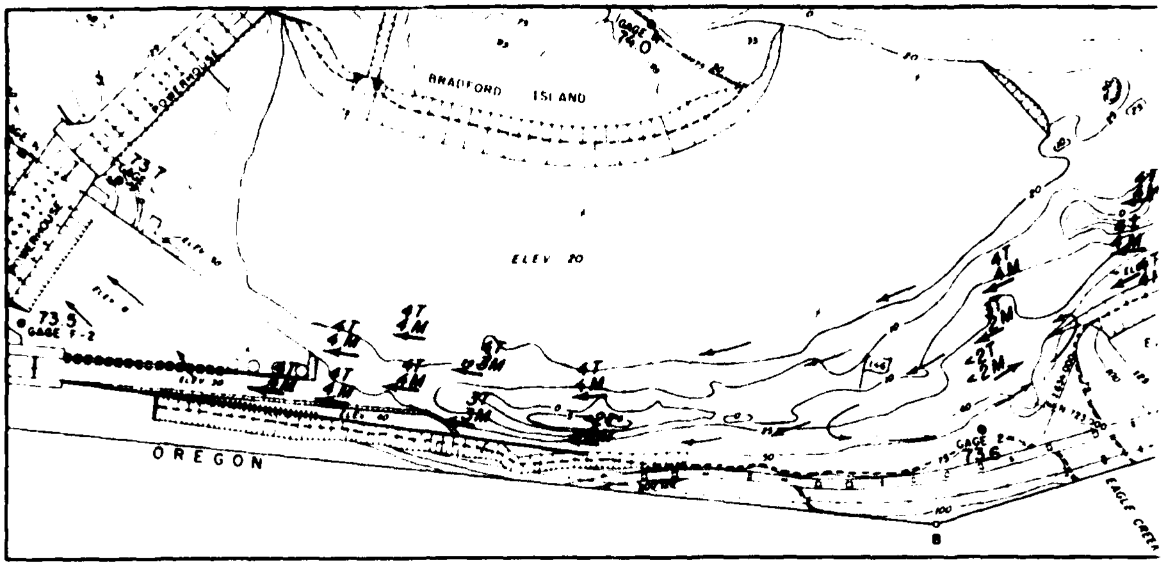


SITE D NAVIGATION LOCK
UPSTREAM APPROACH CHANNEL FILL

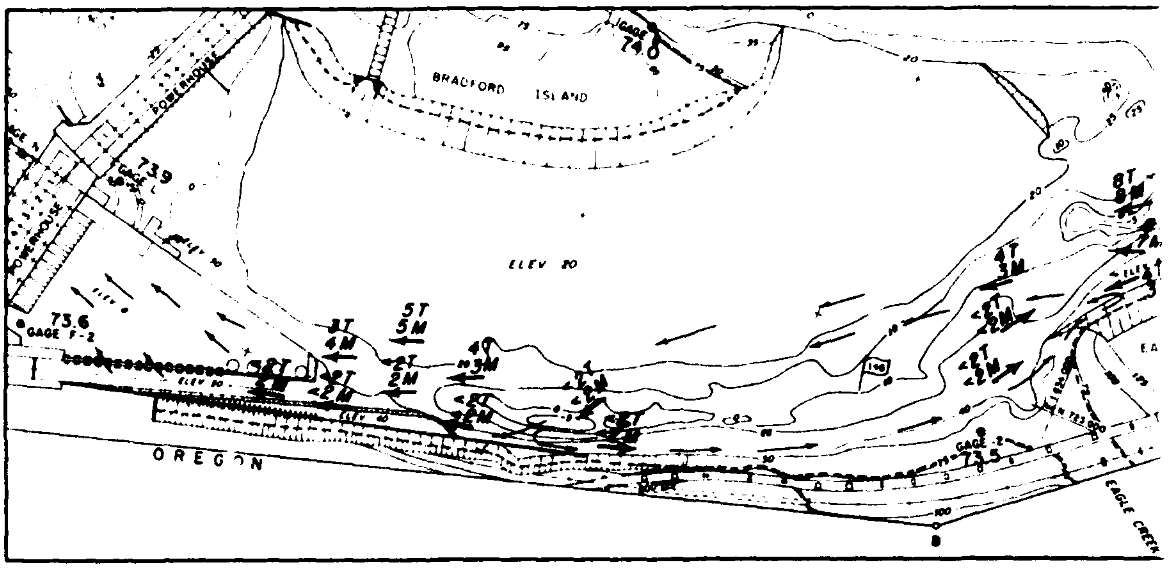
EXISTING CONDITION AND PLANS 1 TO 4

(30/2)

30/3



ORIGINAL NAVIGATION CHANNEL



ORIGINAL NAVIGATION CHANNEL

LEGEND

VELOCITIES MEASURED IN FPS
T 10-FT DEPTH
M 20-FT DEPTH

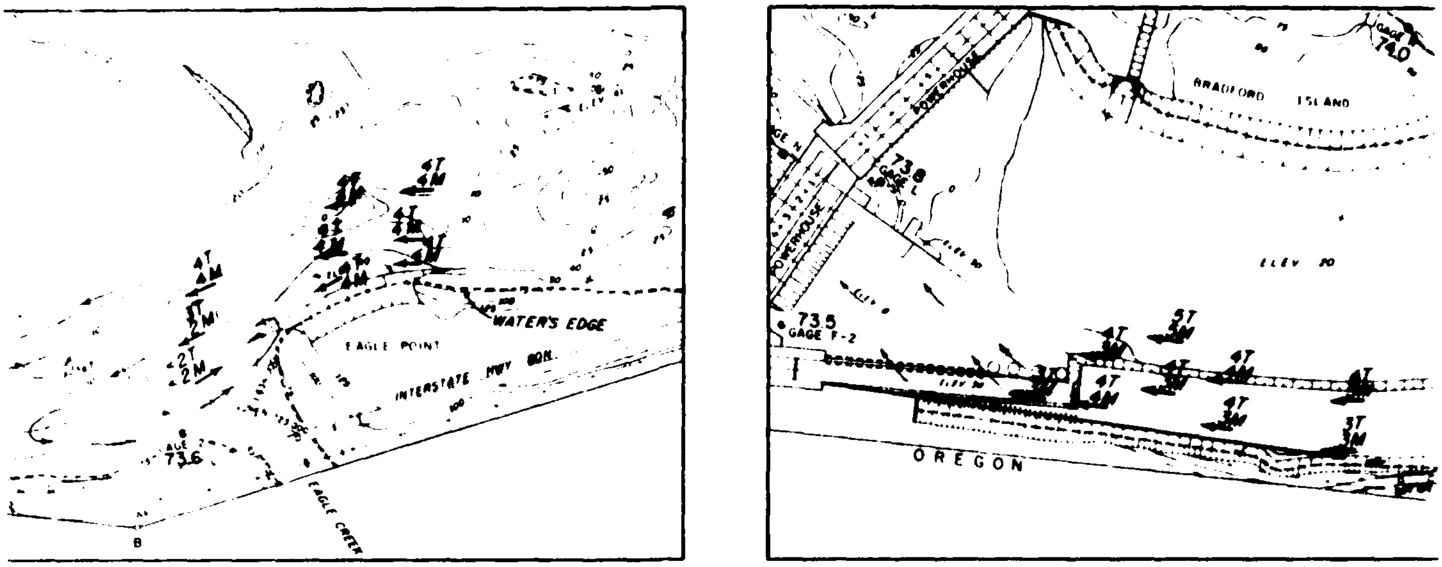
FLOW DISTRIBUTION

RIVER DISCHARGES	300 0(
EXISTING POWERHOUSE UNITS 1 TO 10	141 0(
PLAN U POWERHOUSE UNITS 1 TO 6	132 0(
SPILLWAY BAYS 1 AND 18	2 4(
SPILLWAY BAYS 2 TO 17	24 6(

*INCLUDES FISHWAY FLOWS

1

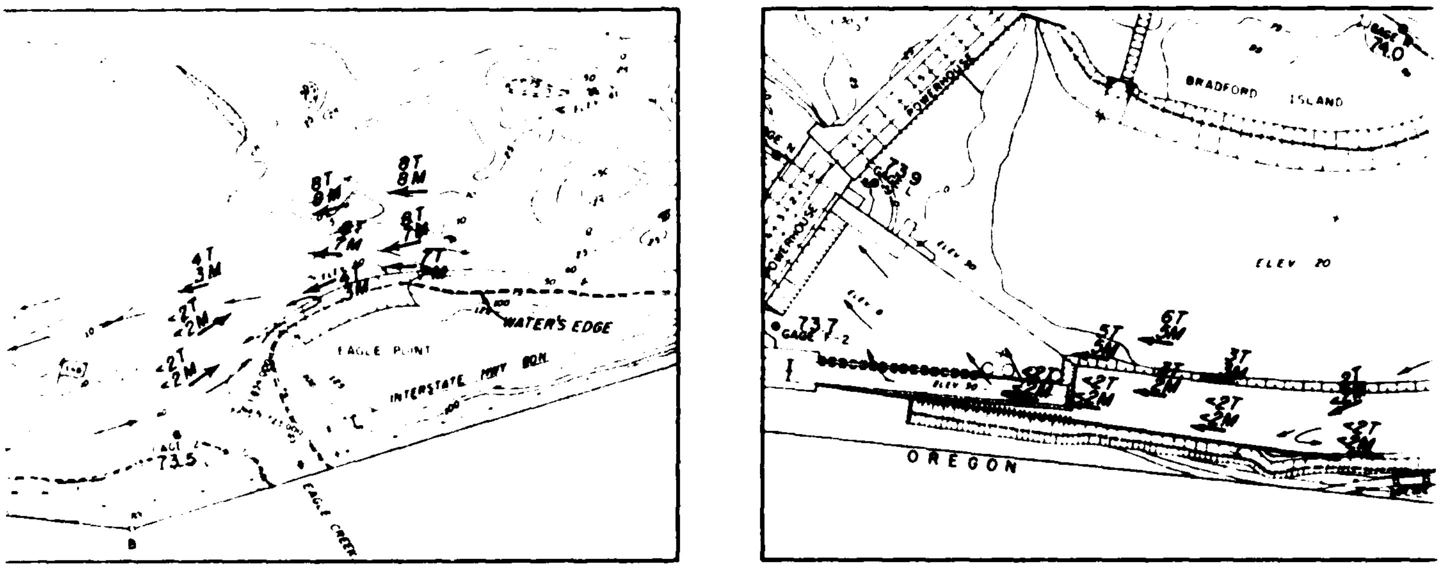
Plate 30



CHANNEL

NAVIGATION

RIVER DISCHARGE 300 000 CFS



CHANNEL

NAVIGATION

RIVER DISCHARGE 600 000 CFS

FLOW DISTRIBUTION

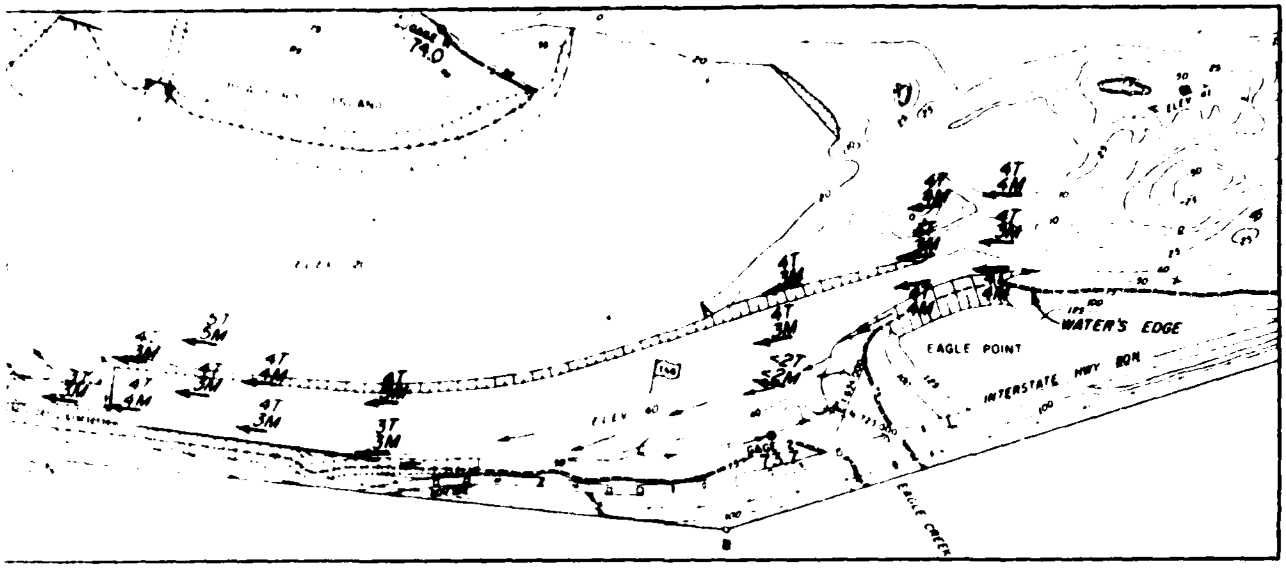
HARGES	300 000 CFS	600 000 CFS
POWERHOUSE UNITS 1 TO 10	141 000 CFS*	142 000 CFS*
WERHOUSE UNITS 1 TO 6	132 000 CFS*	132 000 CFS*
BAYS 1 AND 18	2 400 CFS	2 400 CFS
BAYS 2 TO 17	24 600 CFS*	323 600 CFS*

*INCLUDES FISHWAY FLOWS

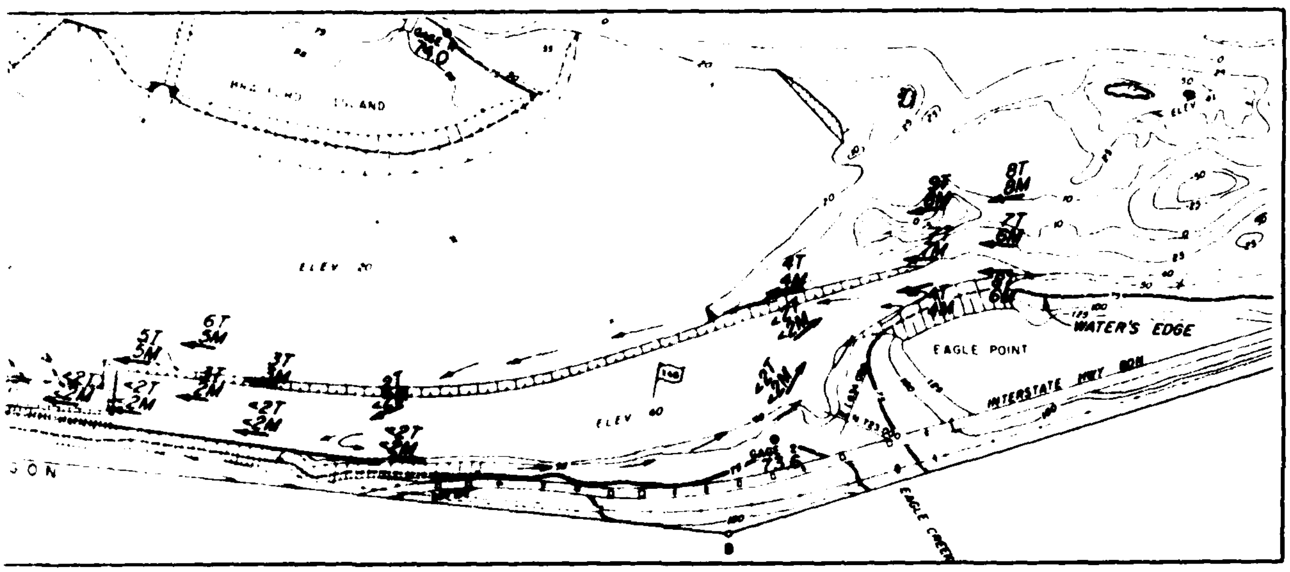
2

SCALE

0 500 1000 1500



NAVIGATION CHANNEL PLAN 4 FILL



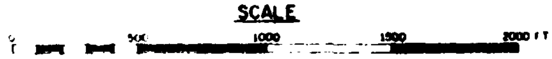
NAVIGATION CHANNEL PLAN 4 FILL

SITE PLAN D

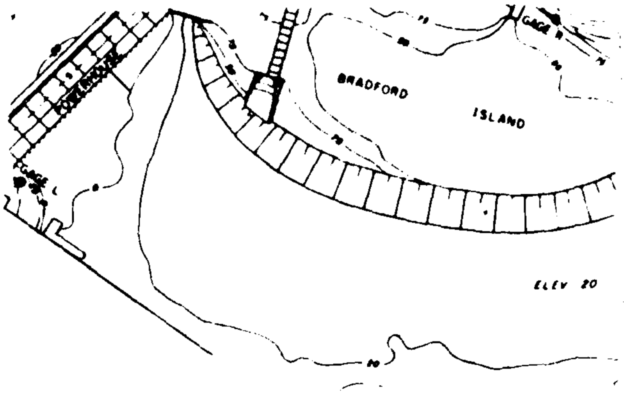
FLOW CONDITIONS

BRADFORD ISLAND PLAN 5 EXCAVATION
EAGLE POINT PLAN 3 EXCAVATION

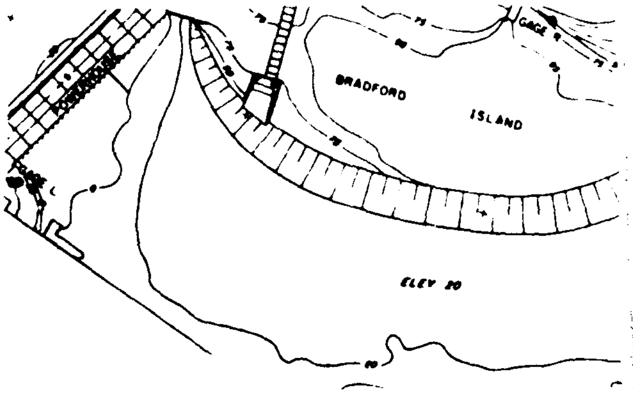
EXISTING AND PLAN D POWERHOUSES OPERATING
RIVER DISCHARGES 300 000 AND 600 000 CFS



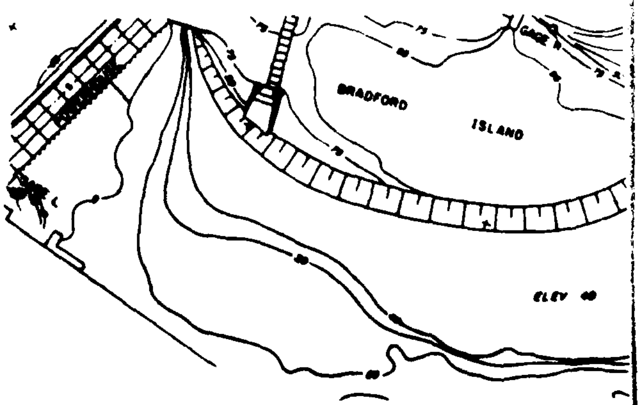
(2) of (5)



PLAN 6-A



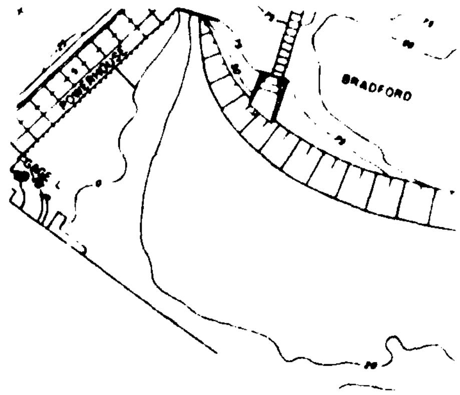
PLAN 6-C



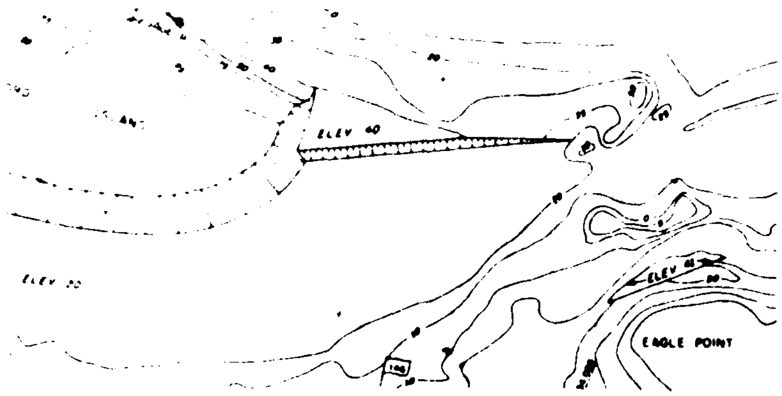
PLAN 6-E

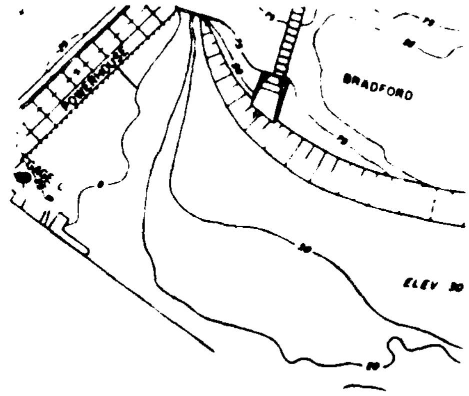
1

Plate 21

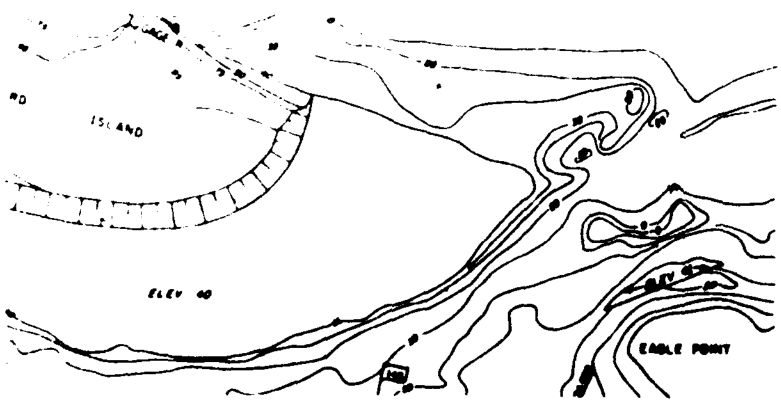


PLAN 6-A

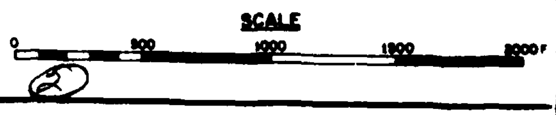


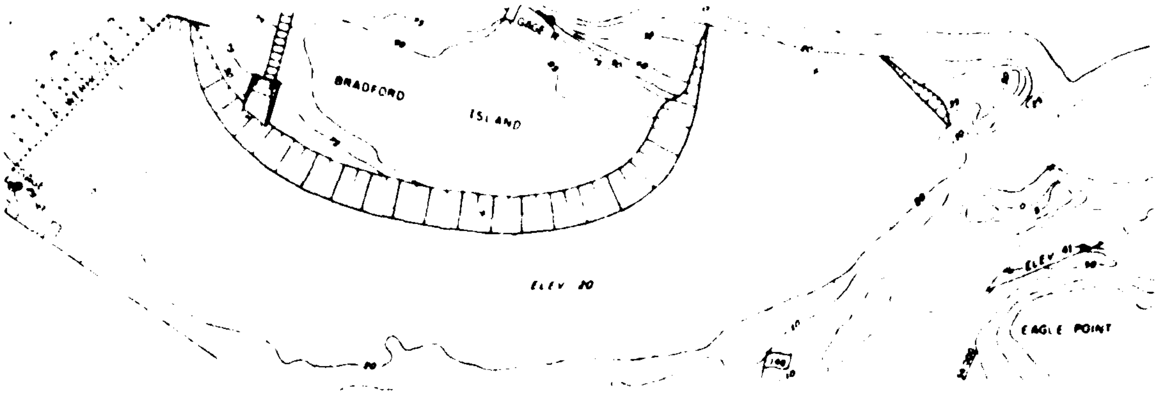


PLAN 6-C

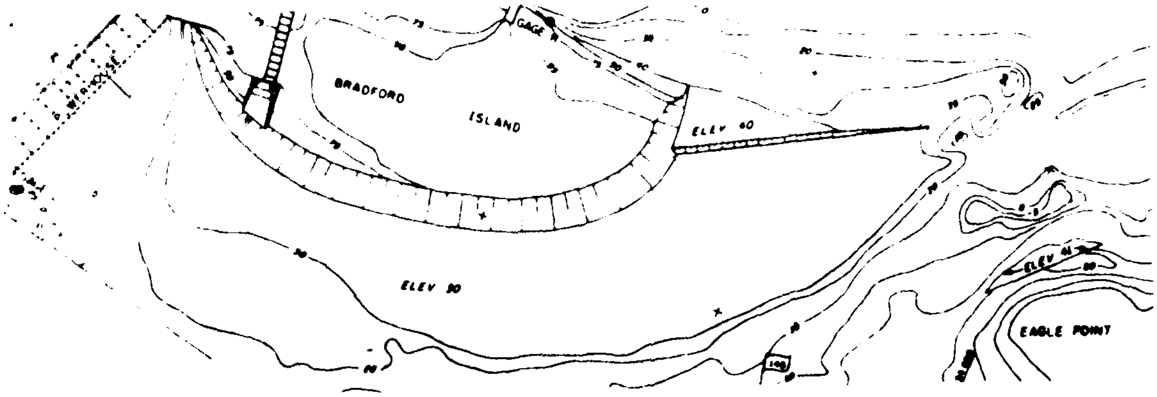


PLAN 6-E





PLAN 6-B



PLAN 6-D

SITE E POWERHOUSE
BRADFORD ISLAND EXCAVATION
PLANS 6-A TO 6-E

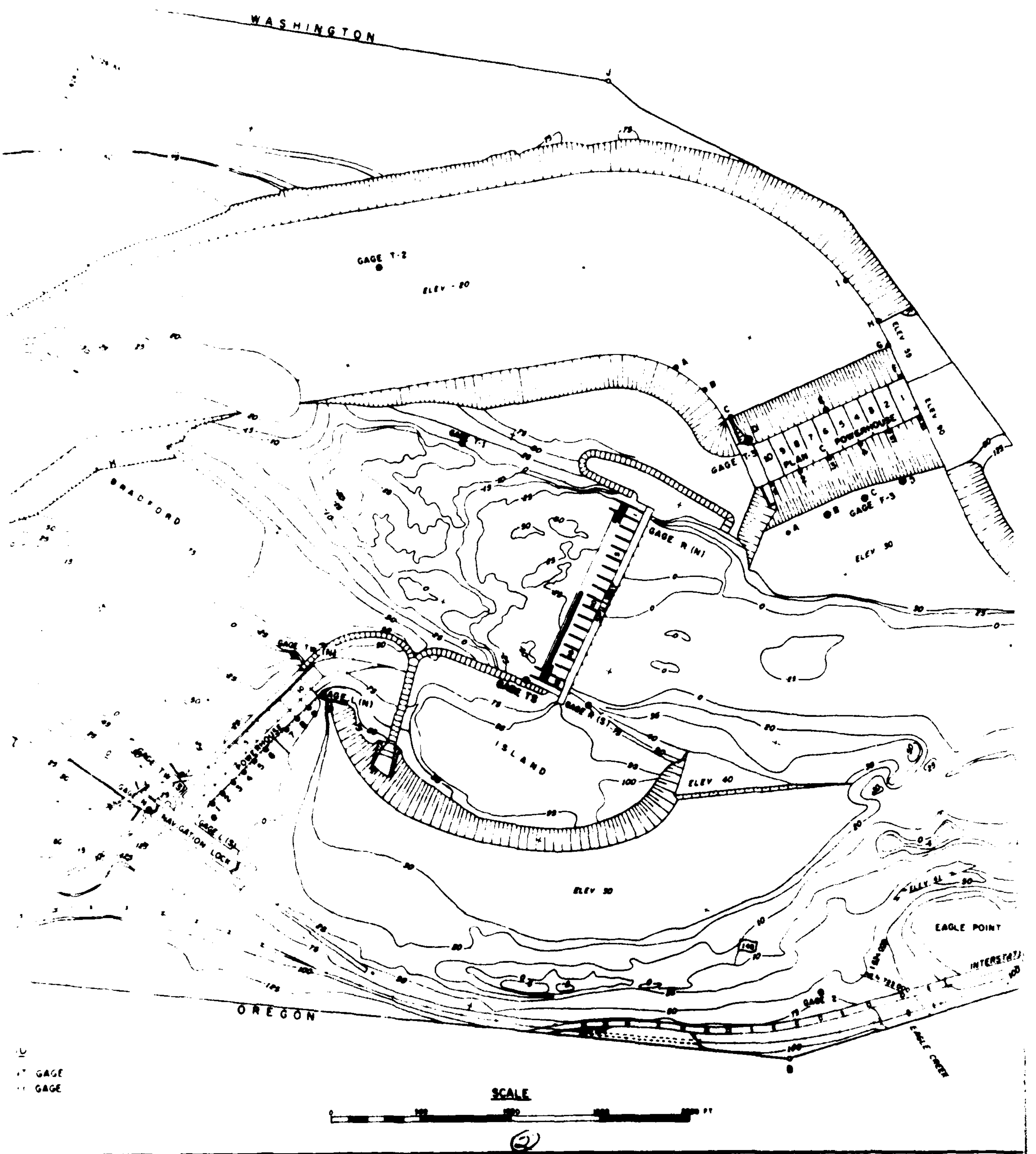
SCALE
0 500 1000 1500 2000 FT

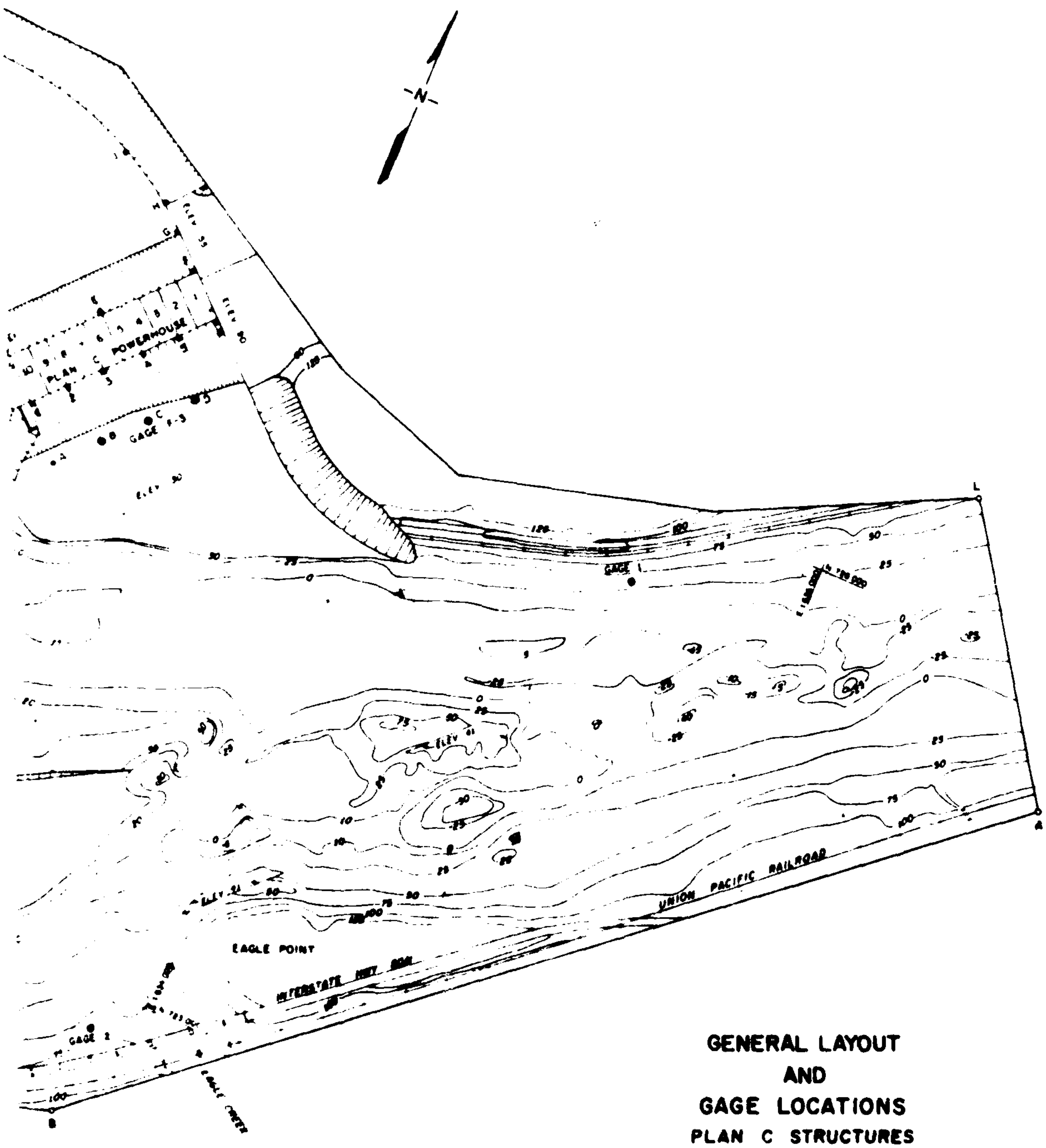
PLATE 21


HAMILTON SLOUGH
GAGE 4
GAGE 3
GAGE 5
BRADFORD
NAVIGATION LOCK
TURKEY CREEK
LEGEND
PERMANENT GAGE
TEMPORARY GAGE

(1)

Plate 22


WASHINGTON
GAGE T-2
ELEV 80
ELEV 50
POWERHOUSE
PLAN C
GAGE T-3
GAGE F-3
GAGE R(N)
ELEV 30
BRADFORD
GAGE TS
GAGE L(N)
POWERHOUSE
ISLAND
ELEV 40
NAVIGATION LOCK
GAGE L(S)
ELEV 30
EAGLE POINT
INTERSTATE
EAGLE CREEK
OREGON
GAGE
GAGE
SCALE
0
500
1000
1500
2000 FT



GENERAL LAYOUT
AND
GAGE LOCATIONS
PLAN C STRUCTURES
BRADFORD ISLAND PLAN B EXCAVATION

3 of 3

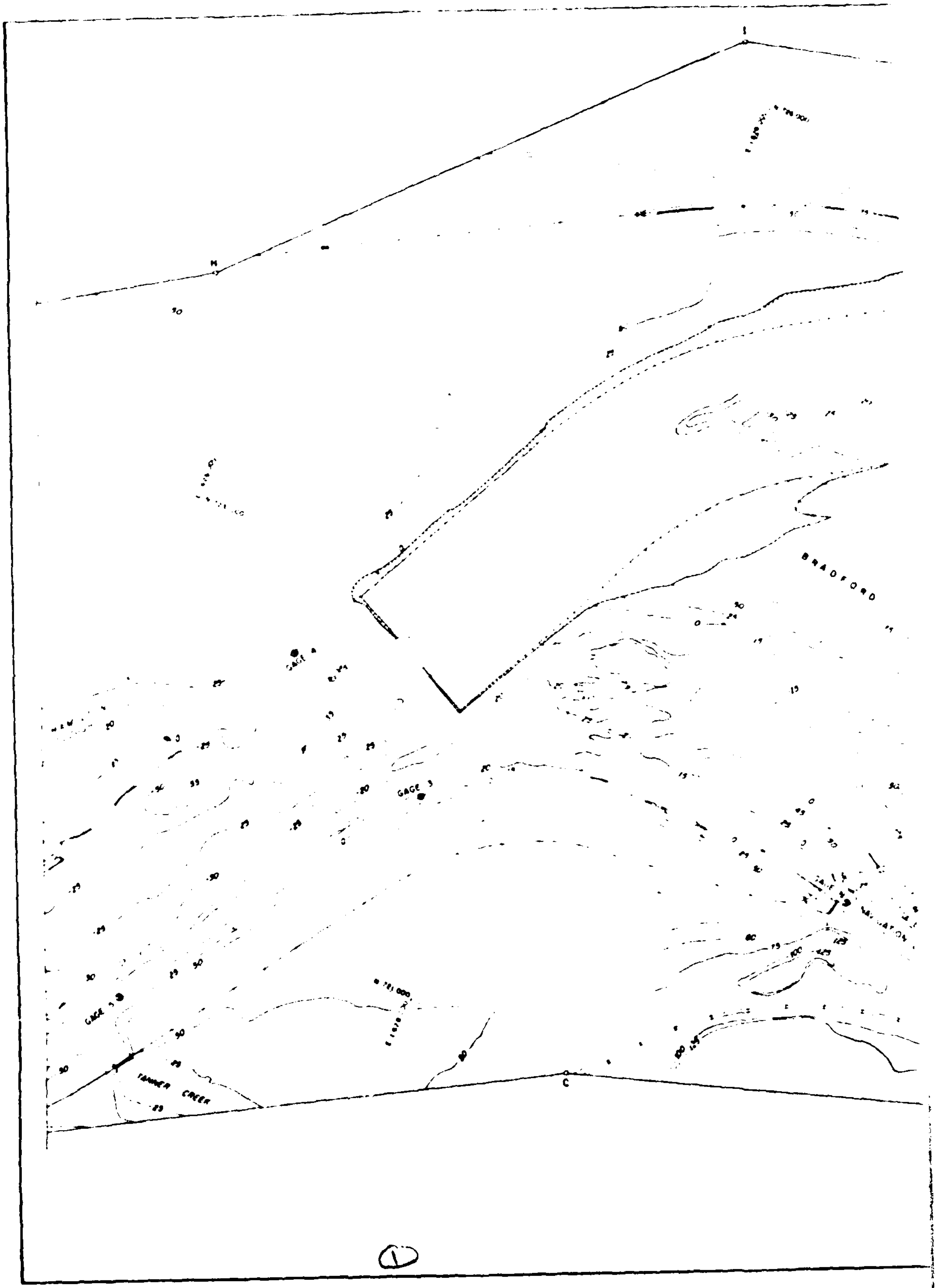
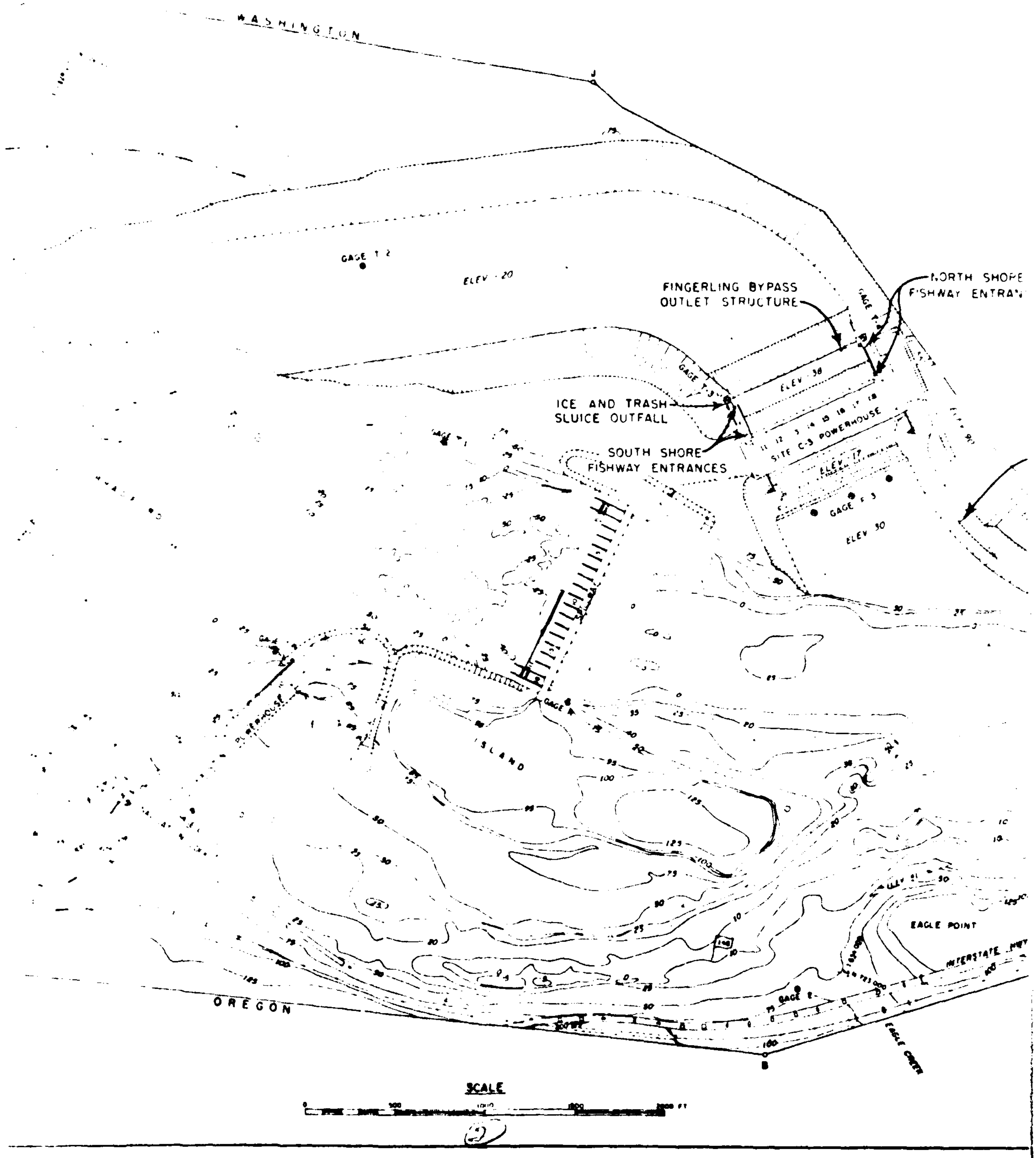
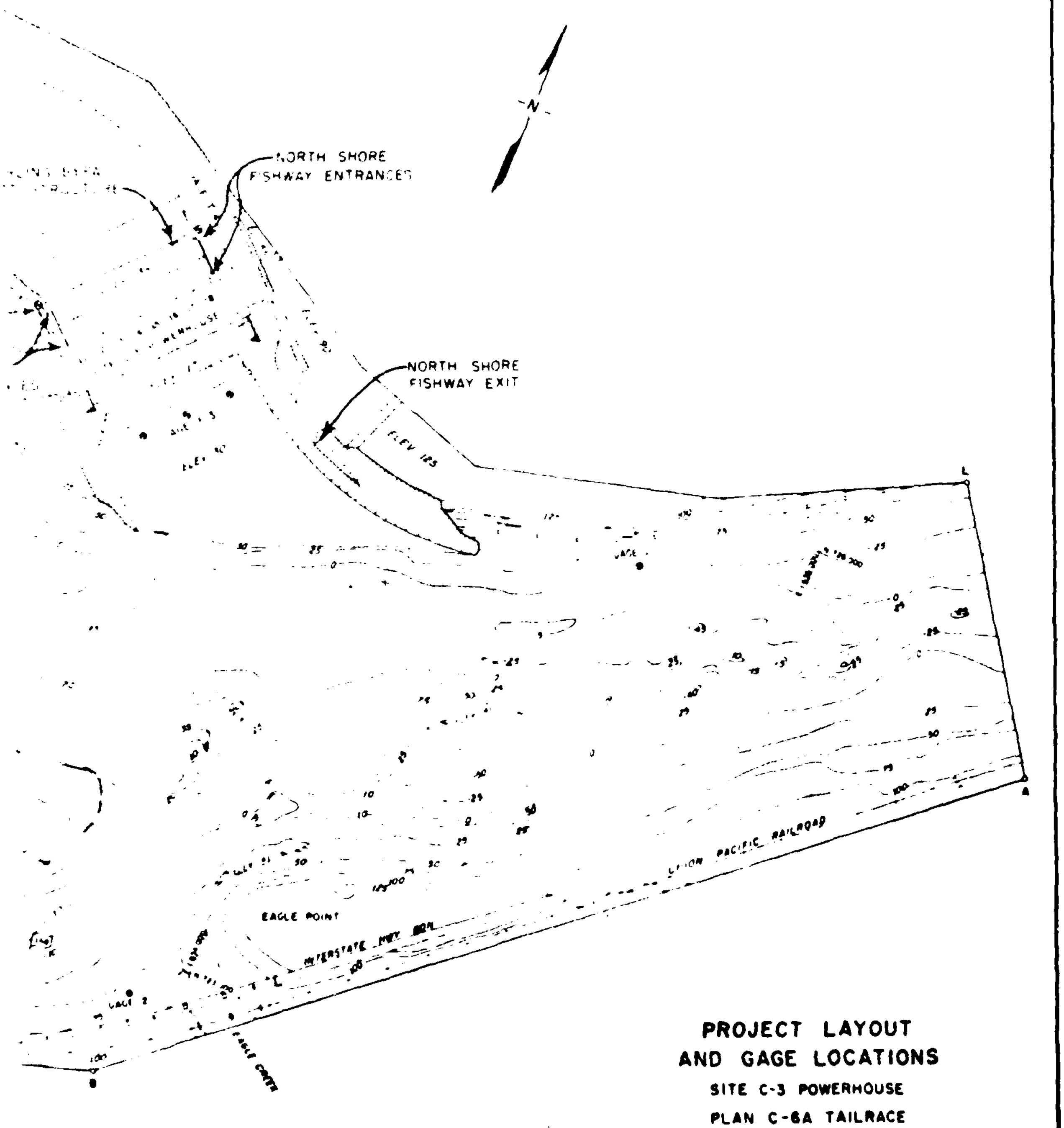


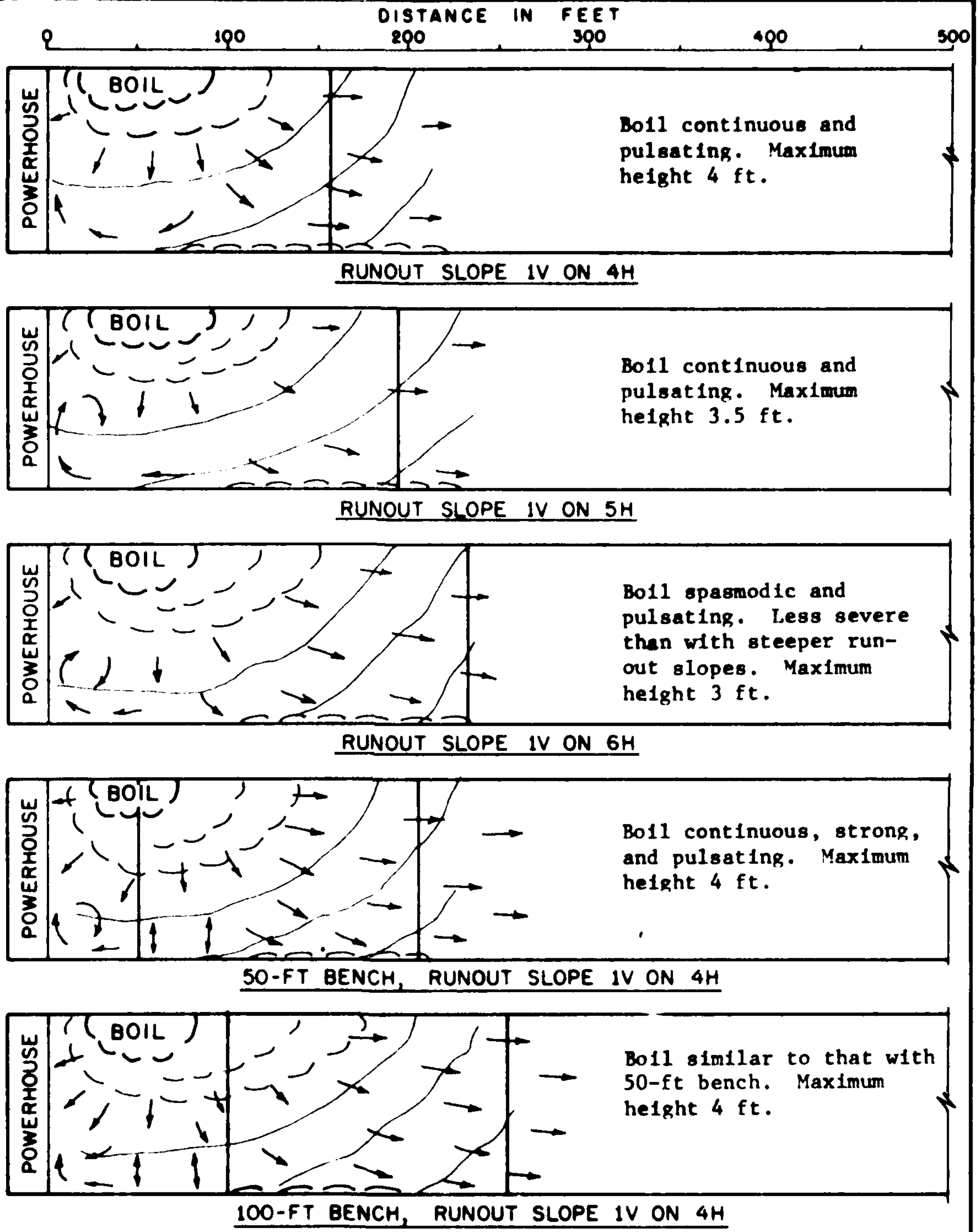
Plate 23


WASHINGTON
GAGE T-2
ELEV 20
FINGERLING BYPASS
OUTLET STRUCTURE
NORTH SHORE
FISHWAY ENTRAN
ICE AND TRASH
SLUICE OUTFALL
SOUTH SHORE
FISHWAY ENTRANCES
SITE C-3 POWERHOUSE
GAGE F-3
ELEV 30
POWERHOUSE
ISLAND
EAGLE POINT
INTERSTATE HWY
OREGON
EAGLE CREEK
SCALE



PROJECT LAYOUT
AND GAGE LOCATIONS
SITE C-3 POWERHOUSE
PLAN C-6A TAILRACE
PLAN C-1 APPROACH

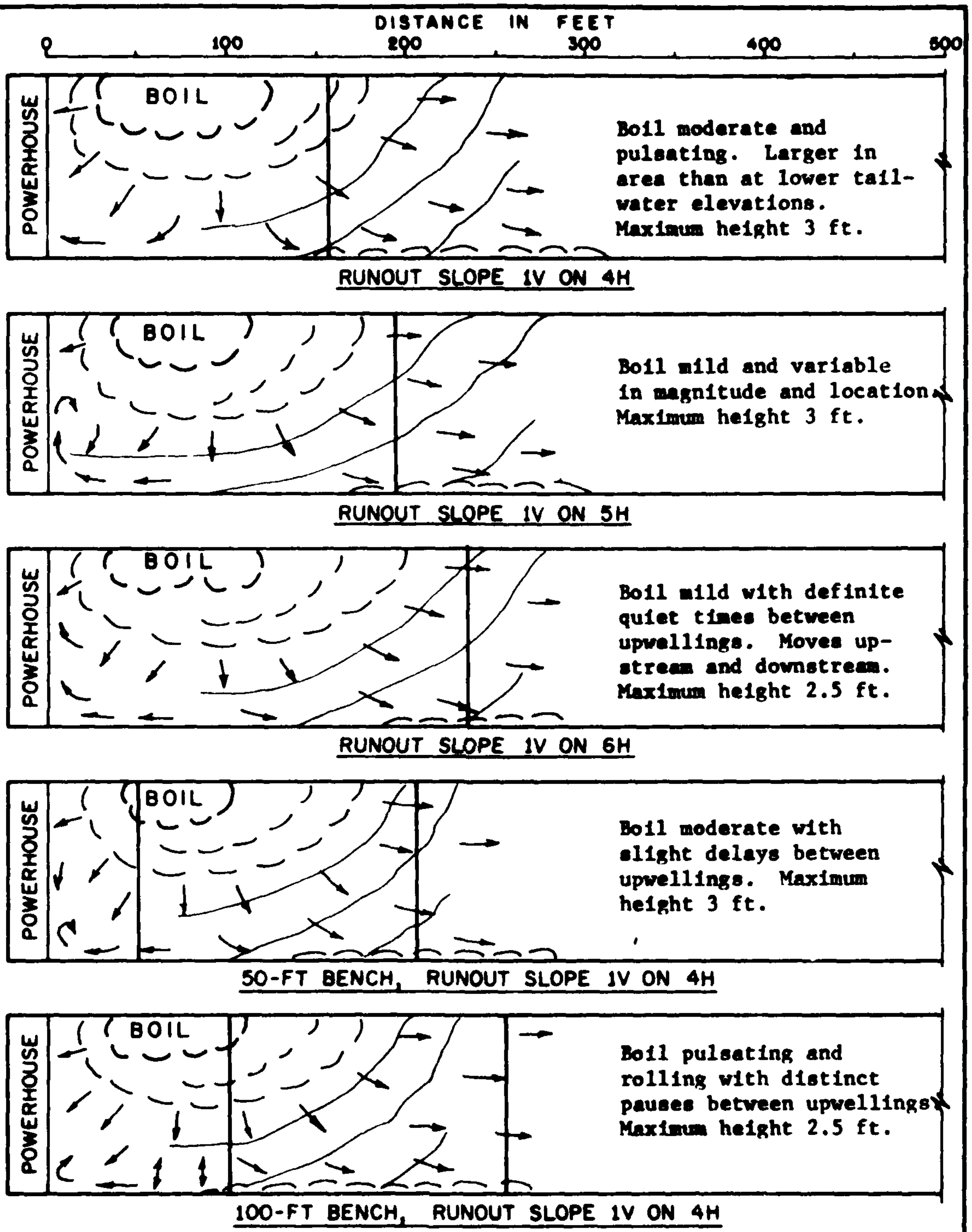
3 of 3



TAILWATER ELEVATION 10

EFFECT OF TAILRACE DESIGN ON UPWELLING

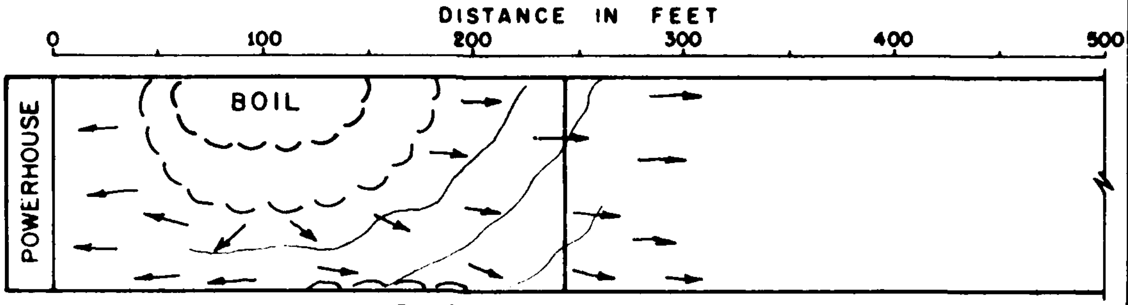
DRAFT TUBE INVERT SLOPE 1V ON 3.5H



TAILWATER ELEVATION 25

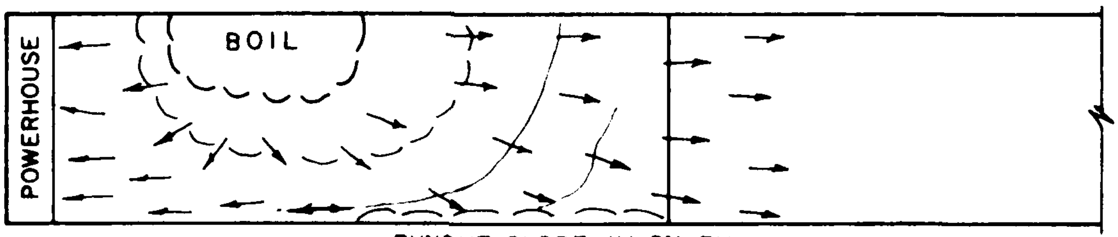
EFFECT OF TAILRACE DESIGN ON UPWELLING

DRAFT TUBE INVERT SLOPE 1V ON 3.5H



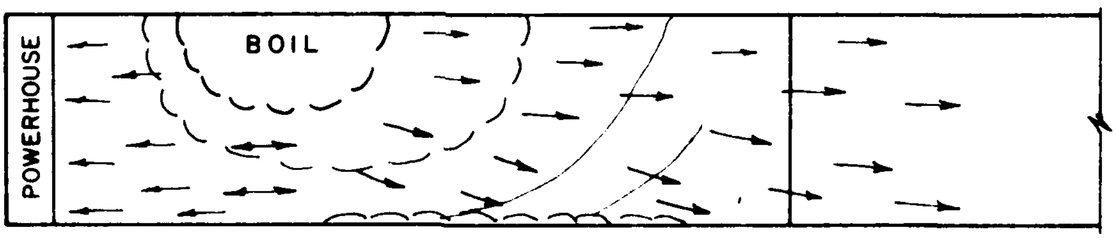
RUNOUT SLOPE 1V ON 4H

Boil undefined and rolling with definite boil only 10% of the time. Maximum height 1.5 ft.



RUNOUT SLOPE 1V ON 5H

Boil pulsating and rolling continuously over half of flume. Maximum height 1.5 ft.



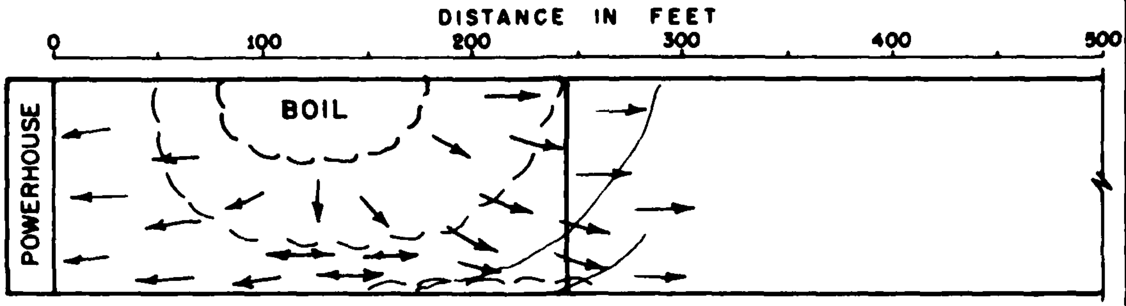
RUNOUT SLOPE 1V ON 6H

Boil was mild pulsating roller.

TAILWATER ELEVATION 10

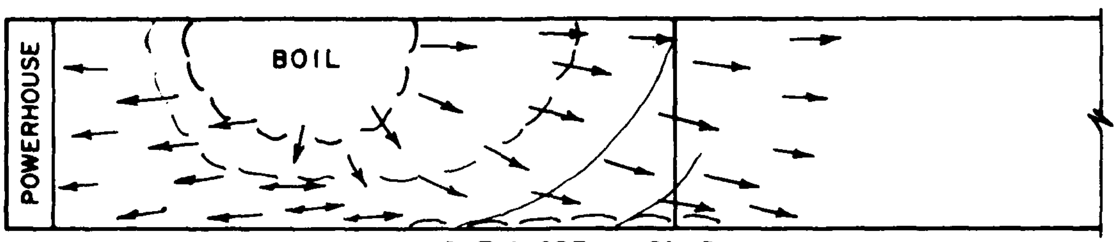
EFFECT OF TAILRACE DESIGN ON UPWELLING

DRAFT TUBE INVERT HORIZONTAL



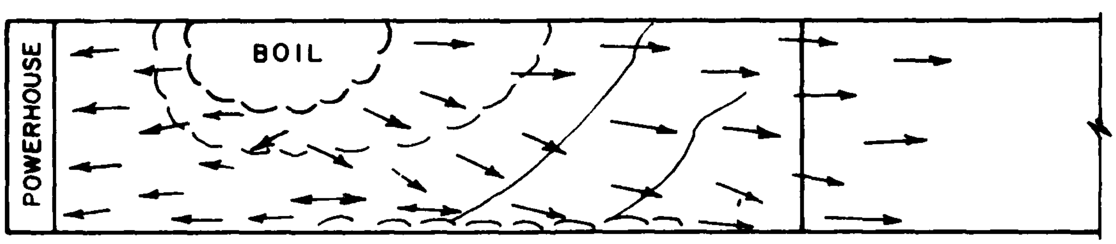
RUNOUT SLOPE 1V ON 4H

Boil was mild irregular roller with quiet water 25% of the time.



RUNOUT SLOPE 1V ON 5H

Boil was very mild covering over half the width
of the flume, quiet water 25% of the time.



RUNOUT SLOPE 1V ON 6H

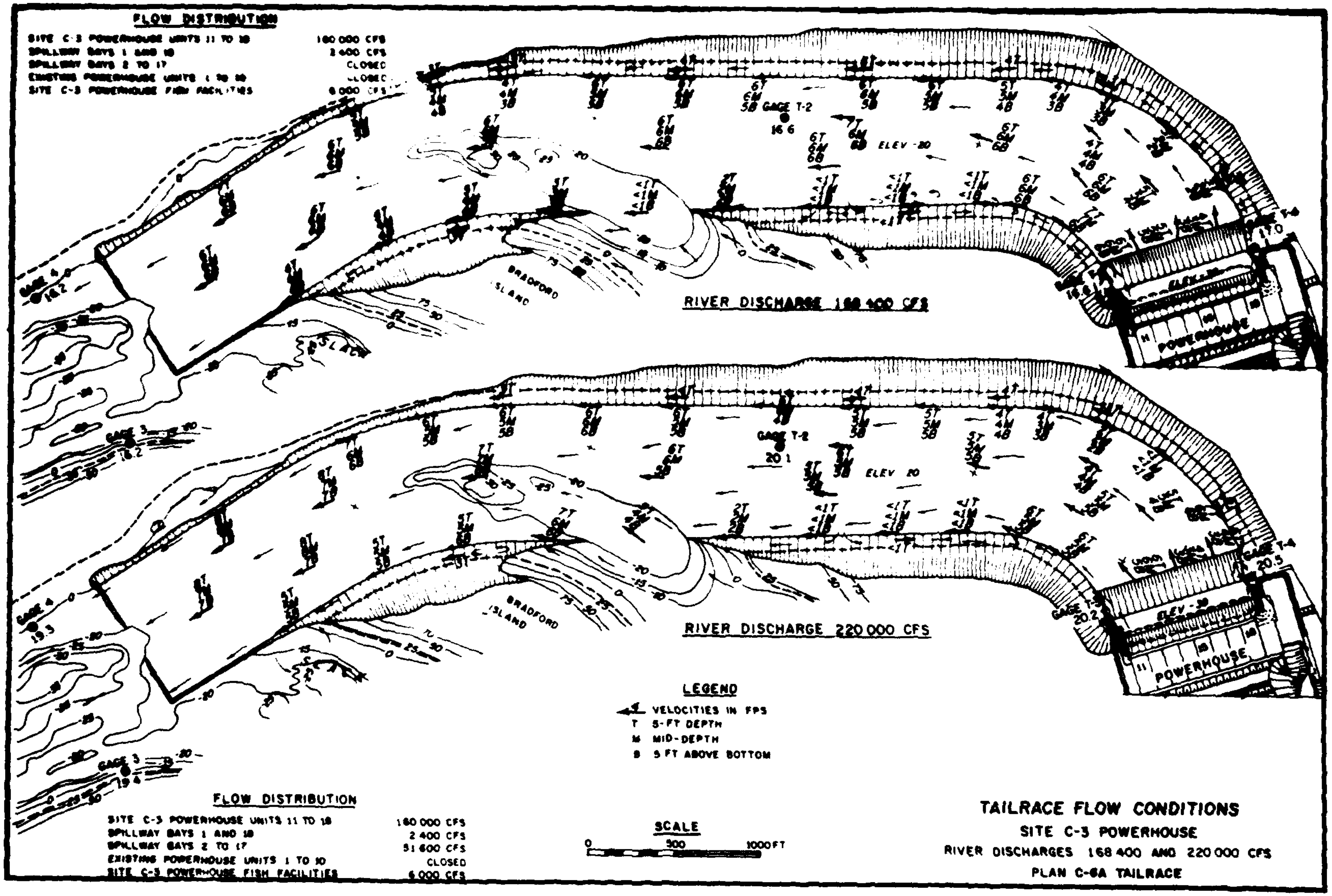
Boil was very mild with quiet water 50% of the time.

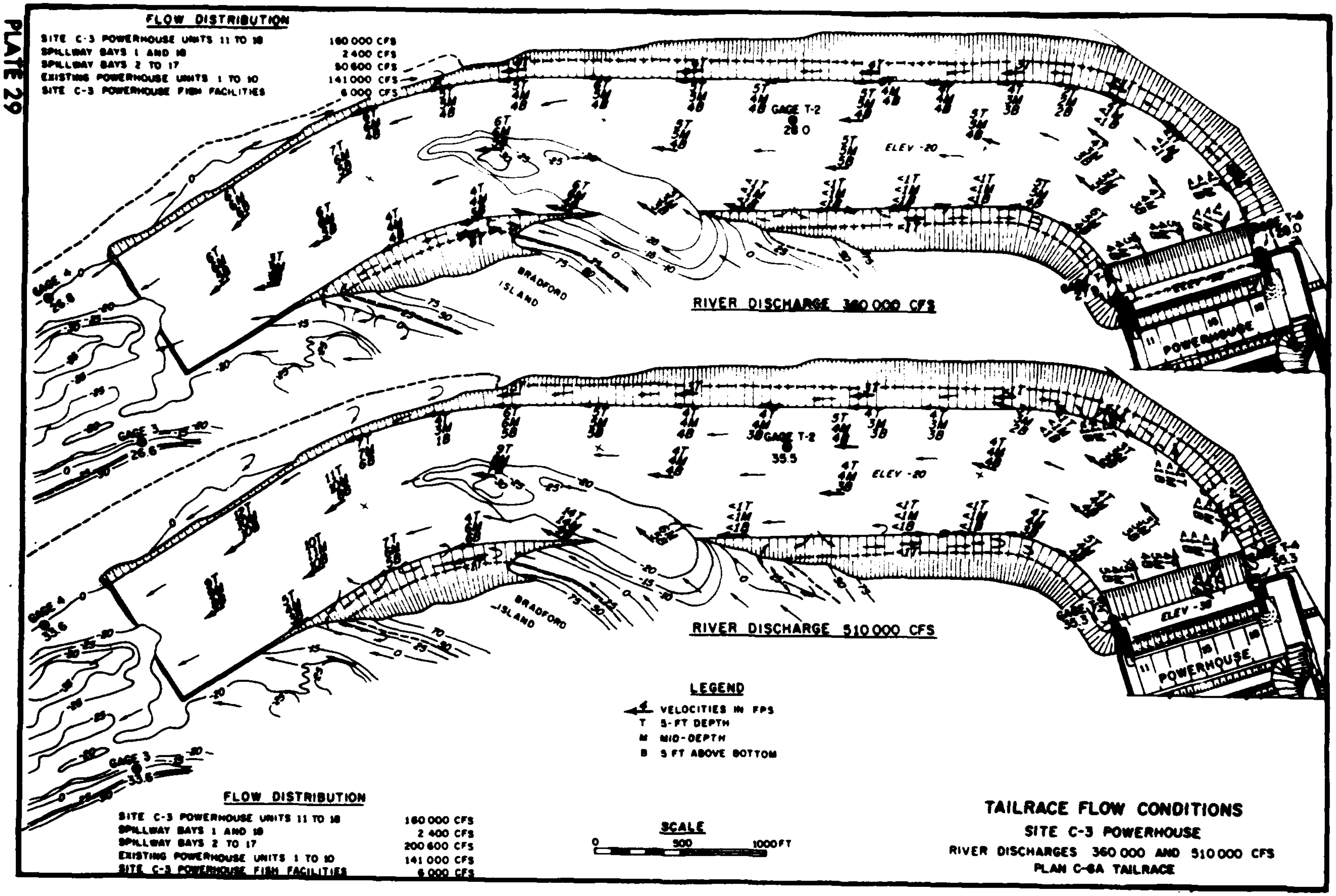
TAILWATER ELEVATION 25

MODEL STUDY
BONNEVILLE SECOND POWERHOUSE

EFFECT OF TAILRACE
DESIGN ON UPWELLING

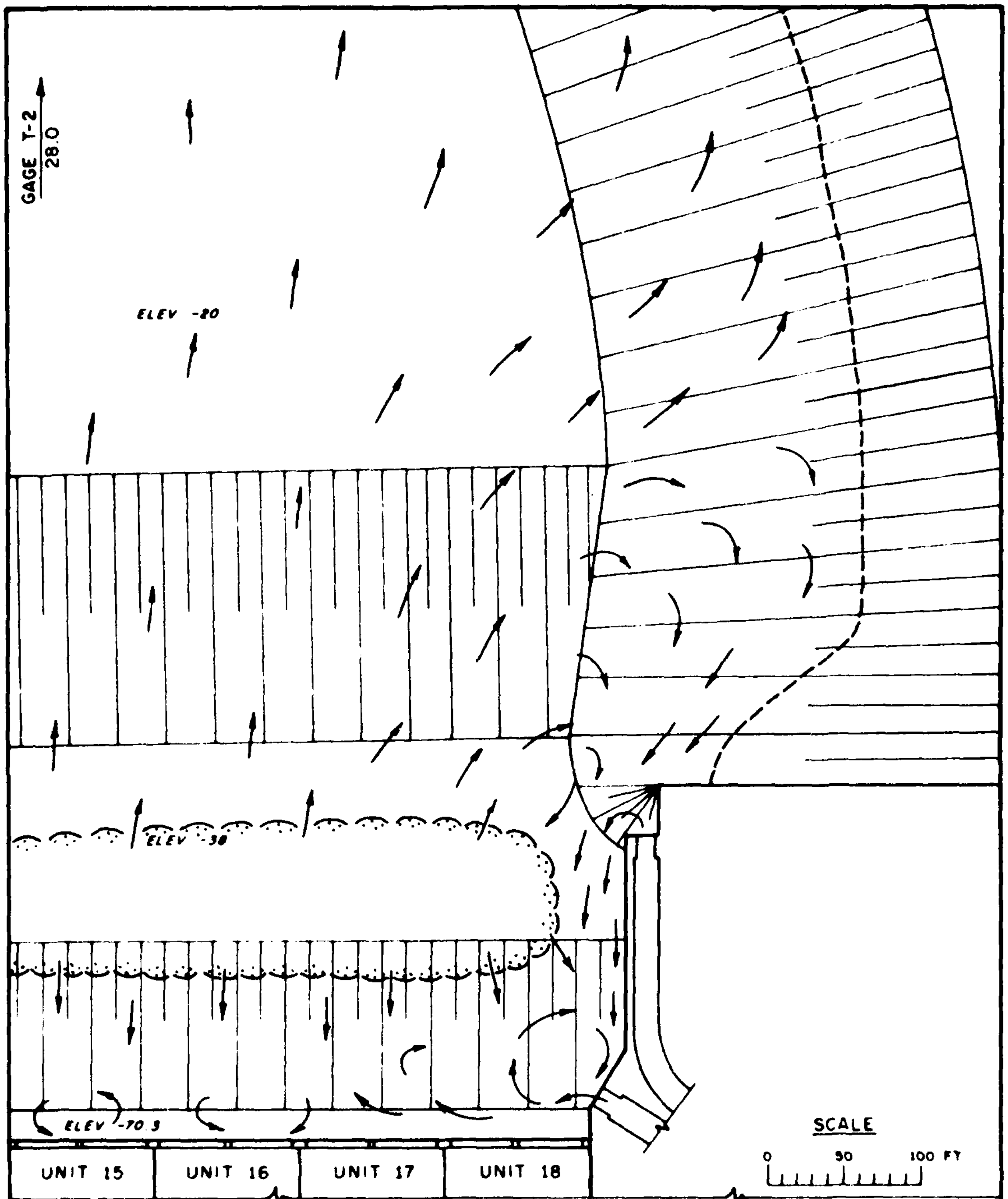
DRAFT TUBE INVERT HORIZONTAL


FLOW DISTRIBUTION
SITE C-3 POWERHOUSE UNITS 11 TO 18 160 000 CFS
SPILLWAY BAYS 1 AND 18 2 400 CFS
SPILLWAY BAYS 2 TO 17 CLOSED
EXISTING POWERHOUSE UNITS 1 TO 10 CLOSED
SITE C-3 POWERHOUSE FISH FACILITIES 6 000 CFS
GAGE T-2
16.6
ELEV -20
GAGE T-4
17.0
BRADFORD ISLAND
GAGE 4
18.2
GAGE 3
18.2
POWERHOUSE
RIVER DISCHARGE 168 400 CFS
GAGE T-2
20.1
ELEV 20
GAGE T-4
20.5
20.2
BRADFORD ISLAND
GAGE 4
19.3
GAGE 3
19.4
POWERHOUSE
RIVER DISCHARGE 220 000 CFS
LEGEND
VELOCITIES IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
FLOW DISTRIBUTION
SITE C-3 POWERHOUSE UNITS 11 TO 18 160 000 CFS
SPILLWAY BAYS 1 AND 18 2 400 CFS
SPILLWAY BAYS 2 TO 17 51 600 CFS
EXISTING POWERHOUSE UNITS 1 TO 10 CLOSED
SITE C-3 POWERHOUSE FISH FACILITIES 6 000 CFS
SCALE
0 500 1000 FT
TAILRACE FLOW CONDITIONS
SITE C-3 POWERHOUSE
RIVER DISCHARGES 168 400 AND 220 000 CFS
PLAN C-6A TAILRACE



TAILRACE FLOW CONDITIONS
SITE C-3 POWERHOUSE
RIVER DISCHARGES 360 000 AND 510 000 CFS
PLAN C-6A TAILRACE

PLATE 29



ORIGINAL PLAN

FLOW DISTRIBUTION

SITE C-3 POWERHOUSE UNITS 11 TO 18	160000 CFS
SPILLWAY BAYS 1 AND 18	2400 CFS
SPILLWAY BAYS 2 TO 17	50600 CFS
EXISTING POWERHOUSE UNITS 1 TO 10	141000 CFS
SITE C-3 POWERHOUSE FISH FACILITIES	6000 CFS

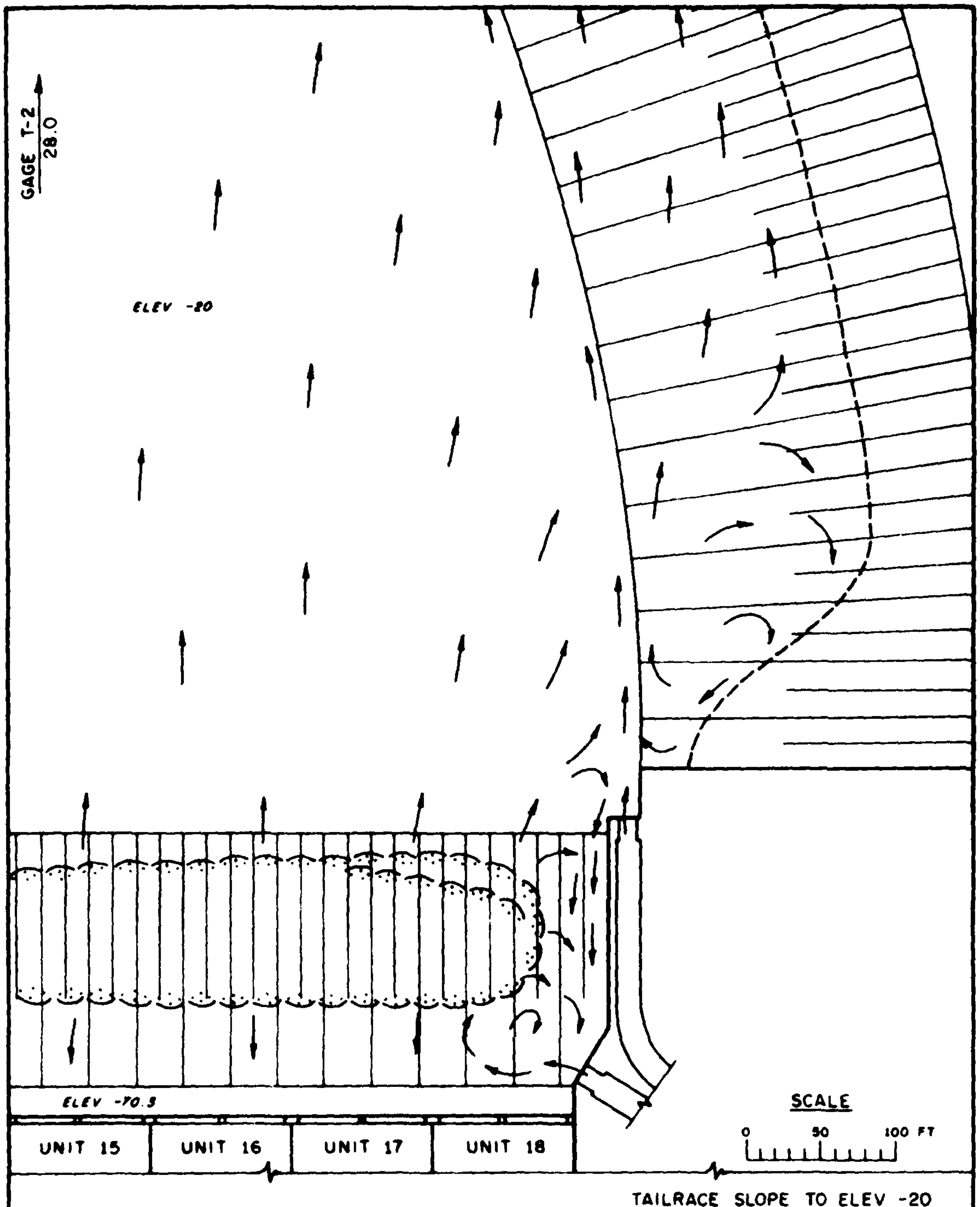
FLOW CONDITIONS

NORTH FISHWAY ENTRANCE

SITE C-3 POWERHOUSE

RIVER DISCHARGE 360000 CFS

PLATE 30



FLOW DISTRIBUTION

SITE C-3 POWERHOUSE UNITS 11 TO 18	160 000 CFS
SPILLWAY BAYS 1 AND 18	2 400 CFS
SPILLWAY BAYS 2 TO 17	50 600 CFS
EXISTING POWERHOUSE UNITS 1 TO 10	141 000 CFS
SITE C-3 POWERHOUSE FISH FACILITIES	6 000 CFS

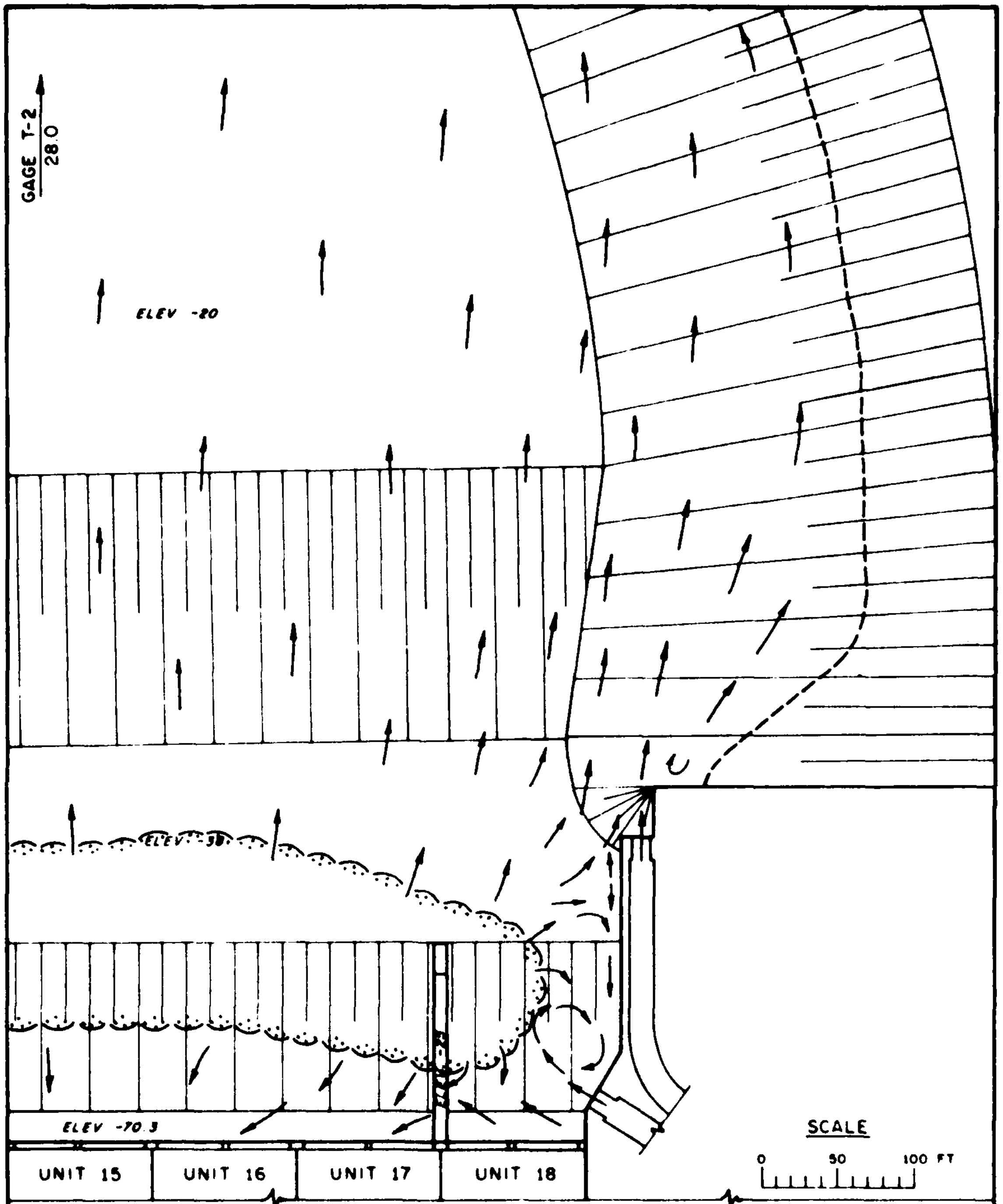
FLOW CONDITIONS

NORTH FISHWAY ENTRANCE

SITE C-3 POWERHOUSE

RIVER DISCHARGE 360 000 CFS

PLATE 31



TRAINING WALL AT ELEV -25

FLOW DISTRIBUTION

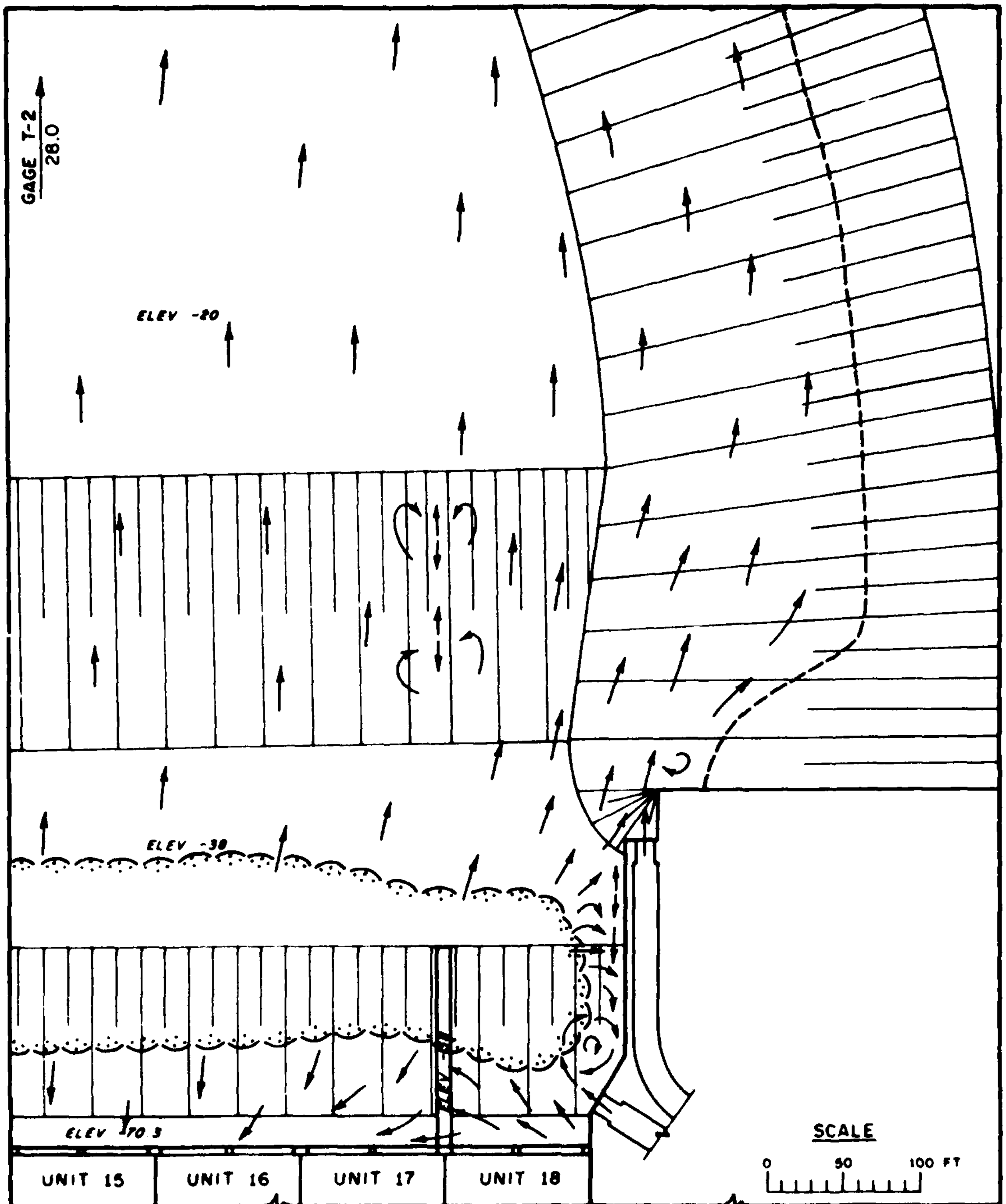
SITE C-3 POWERHOUSE UNITS 11 TO 18	160000 CFS
SPILLWAY BAYS 1 AND 18	2400 CFS
SPILLWAY BAYS 2 TO 17	50600 CFS
EXISTING POWERHOUSE UNITS 1 TO 10	141000 CFS
SITE C-3 POWERHOUSE FISH FACILITIES	6000 CFS

FLOW CONDITIONS

NORTH FISHWAY ENTRANCE

SITE C-3 POWERHOUSE

RIVER DISCHARGE 360000 CFS



TRAINING WALL AT ELEV -38

FLOW DISTRIBUTION

SITE C-3 POWERHOUSE UNITS 11 TO 18	160000 CFS
SPILLWAY BAYS 1 AND 18	2400 CFS
SPILLWAY BAYS 2 TO 17	50600 CFS
EXISTING POWERHOUSE UNITS 1 TO 10	141000 CFS
SITE C-3 POWERHOUSE FISH FACILITIES	6000 CFS

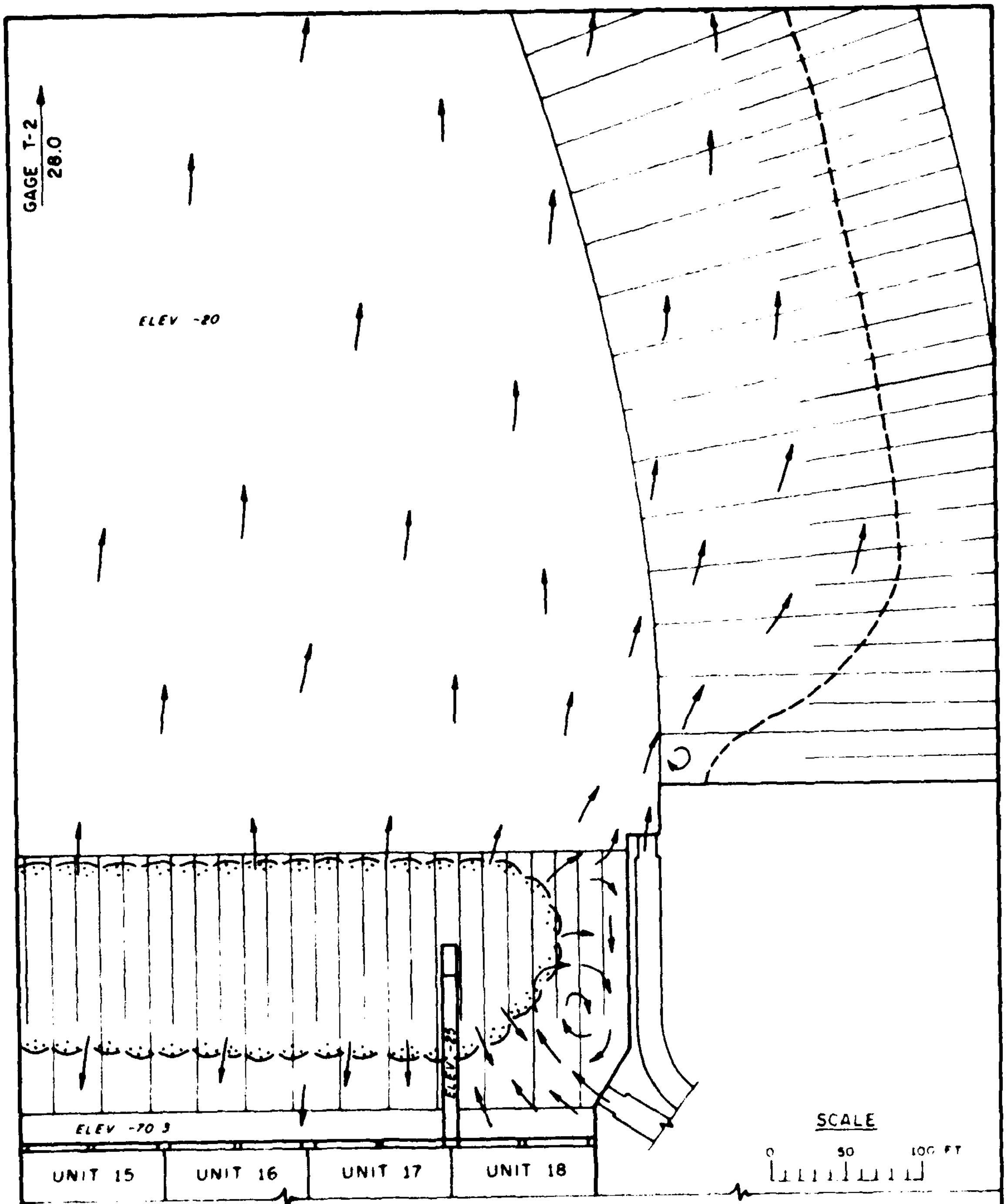
FLOW CONDITIONS

NORTH FISHWAY ENTRANCE

SITE C-3 POWERHOUSE

RIVER DISCHARGE 360000 CFS

PLATE 33



TAILRACE SLOPE TO ELEV -20
TRAINING WALL AT ELEV -25

FLOW DISTRIBUTION

SITE C-3 POWERHOUSE UNITS 11 TO 18	160 000 CFS
SPILLWAY BAYS 1 AND 18	2 400 CFS
SPILLWAY BAYS 2 TO 17	50 600 CFS
EXISTING POWERHOUSE UNITS 1 TO 10	141 000 CFS
SITE C-3 POWERHOUSE FISH FACILITIES	6 000 CFS

FLOW CONDITIONS

NORTH FISHWAY ENTRANCE

SITE C-3 POWERHOUSE

RIVER DISCHARGE 360 000 CFS

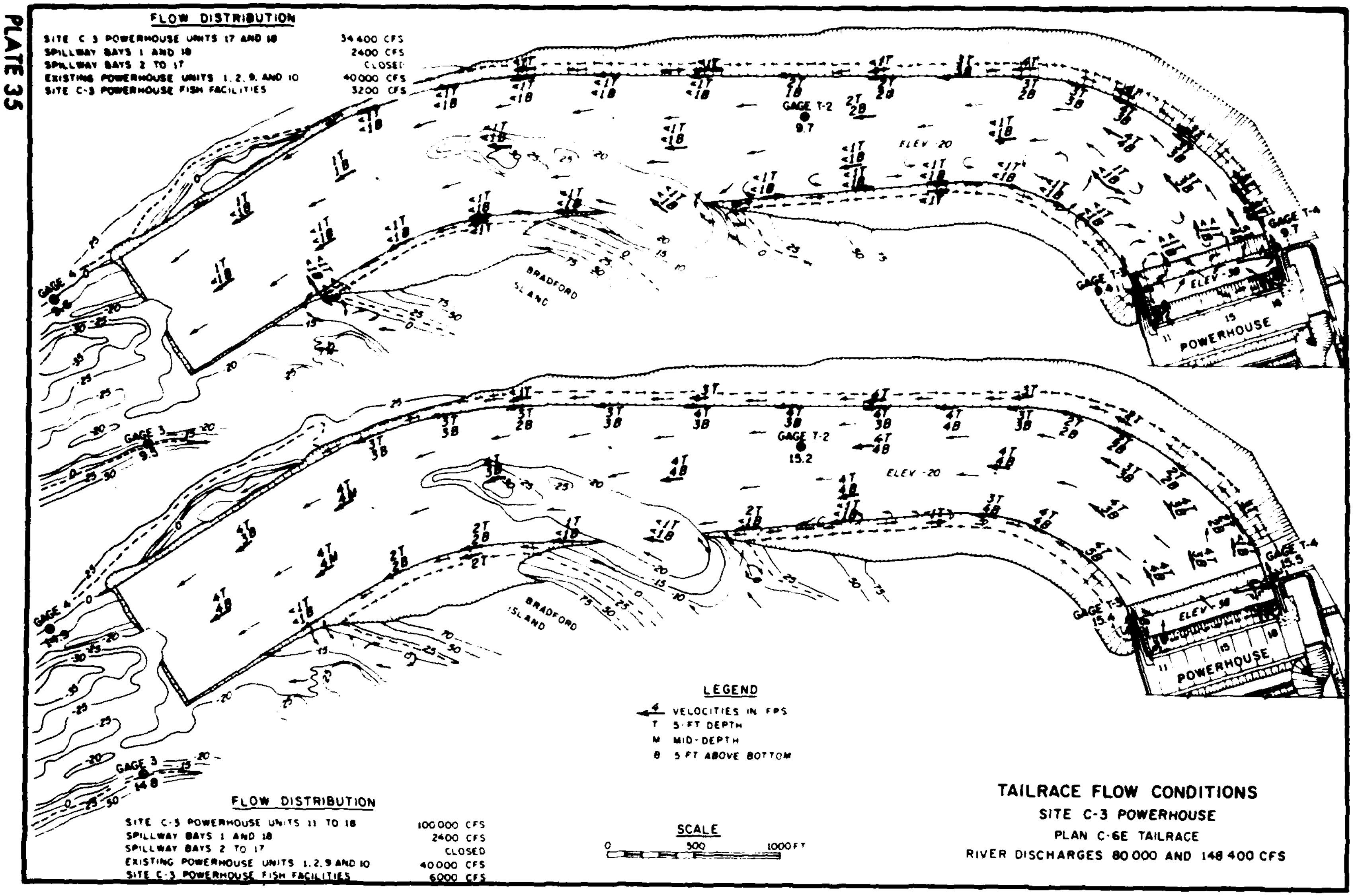
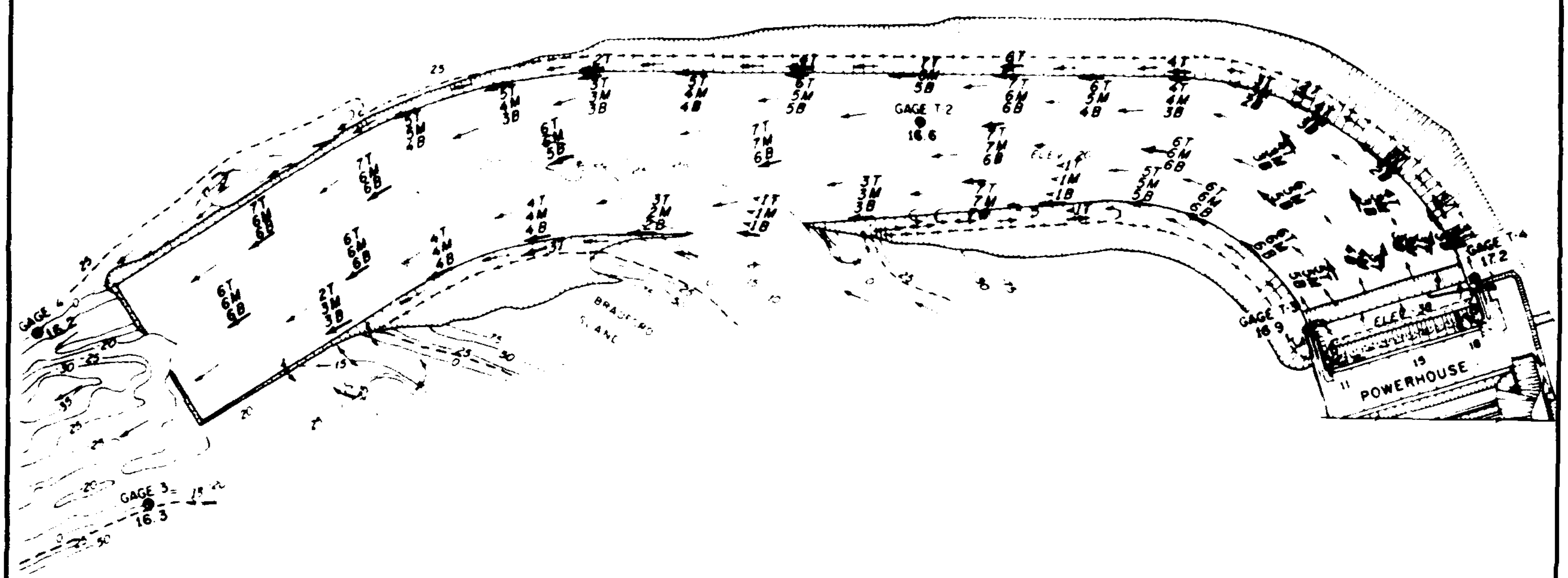

FLOW DISTRIBUTION
SITE C-3 POWERHOUSE UNITS 17 AND 18 34400 CFS
SPILLWAY BAYS 1 AND 18 2400 CFS
SPILLWAY BAYS 2 TO 17 CLOSED
EXISTING POWERHOUSE UNITS 1, 2, 9, AND 10 40000 CFS
SITE C-3 POWERHOUSE FISH FACILITIES 3200 CFS
GAGE T-2
9.7
GAGE T-4
9.7
GAGE T-2
15.2
GAGE T-4
15.5
GAGE T-3
15.4
ELEV -20
POWERHOUSE
BRADFORD ISLAND
GAGE 3
9.3
GAGE 3
14.8
LEGEND
VELOCITIES IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
SCALE
0 500 1000 FT
FLOW DISTRIBUTION
SITE C-3 POWERHOUSE UNITS 11 TO 18 100000 CFS
SPILLWAY BAYS 1 AND 18 2400 CFS
SPILLWAY BAYS 2 TO 17 CLOSED
EXISTING POWERHOUSE UNITS 1, 2, 9 AND 10 40000 CFS
SITE C-3 POWERHOUSE FISH FACILITIES 6000 CFS
TAILRACE FLOW CONDITIONS
SITE C-3 POWERHOUSE
PLAN C-6E TAILRACE
RIVER DISCHARGES 80000 AND 148400 CFS

PLATE 35



FLOW DISTRIBUTION

SITE C-3 POWERHOUSE UNITS	160 000 CFS
SPILLWAY BAYS 1 AND 18	2400 CFS
SPILLWAY BAYS 2 TO 17	CLOSED
EXISTING POWERHOUSE UNITS 1 TO 10	CLOSED
SITE C-3 POWERHOUSE FISH FACILITIES	6000 CFS

LEGEND

4 ← VELOCITIES IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM

SCALE

0 500 1000 FT

TAILRACE FLOW CONDITIONS
SITE C-3 POWERHOUSE
PLAN C-6E TAILRACE
RIVER DISCHARGE 168 400 CFS

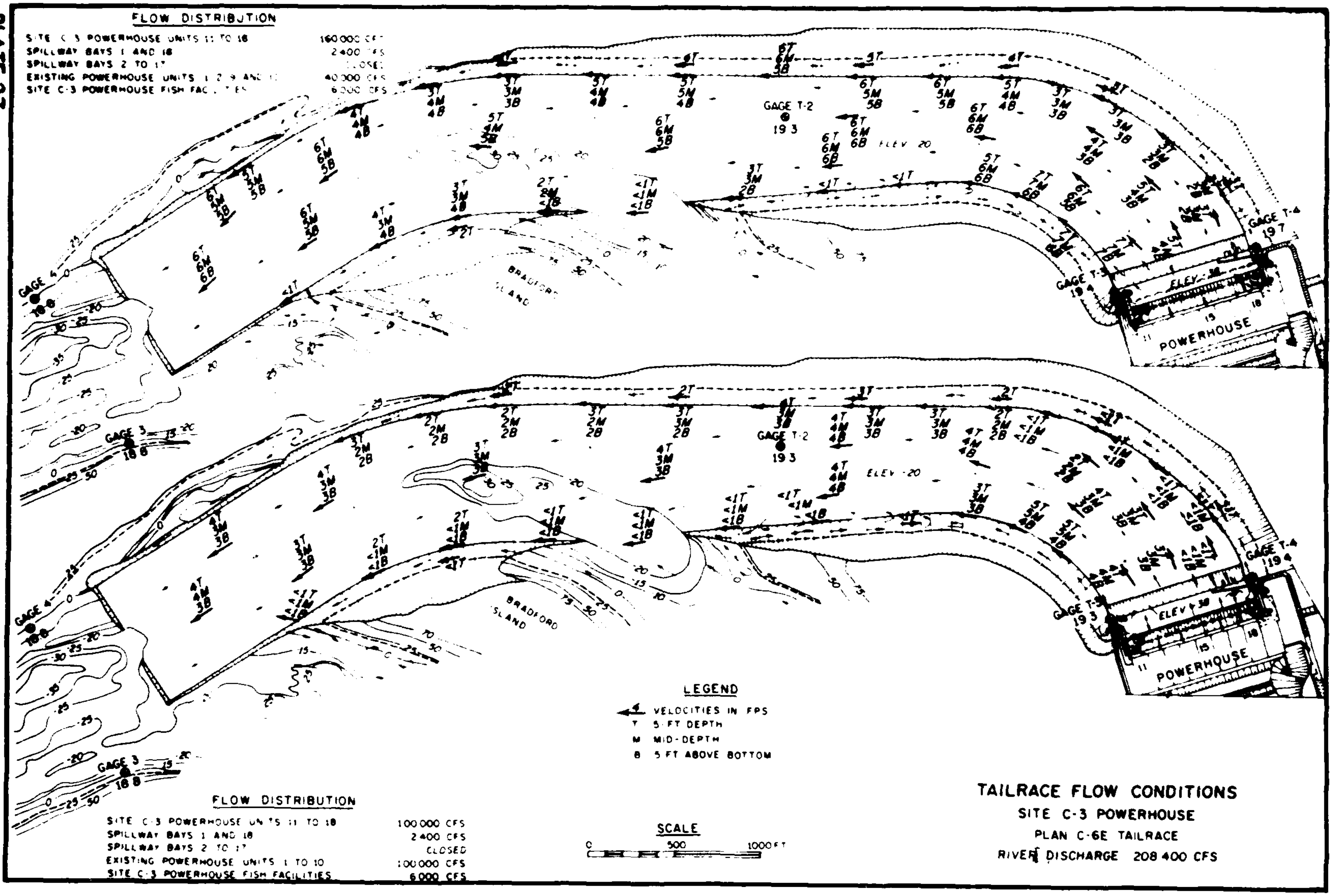
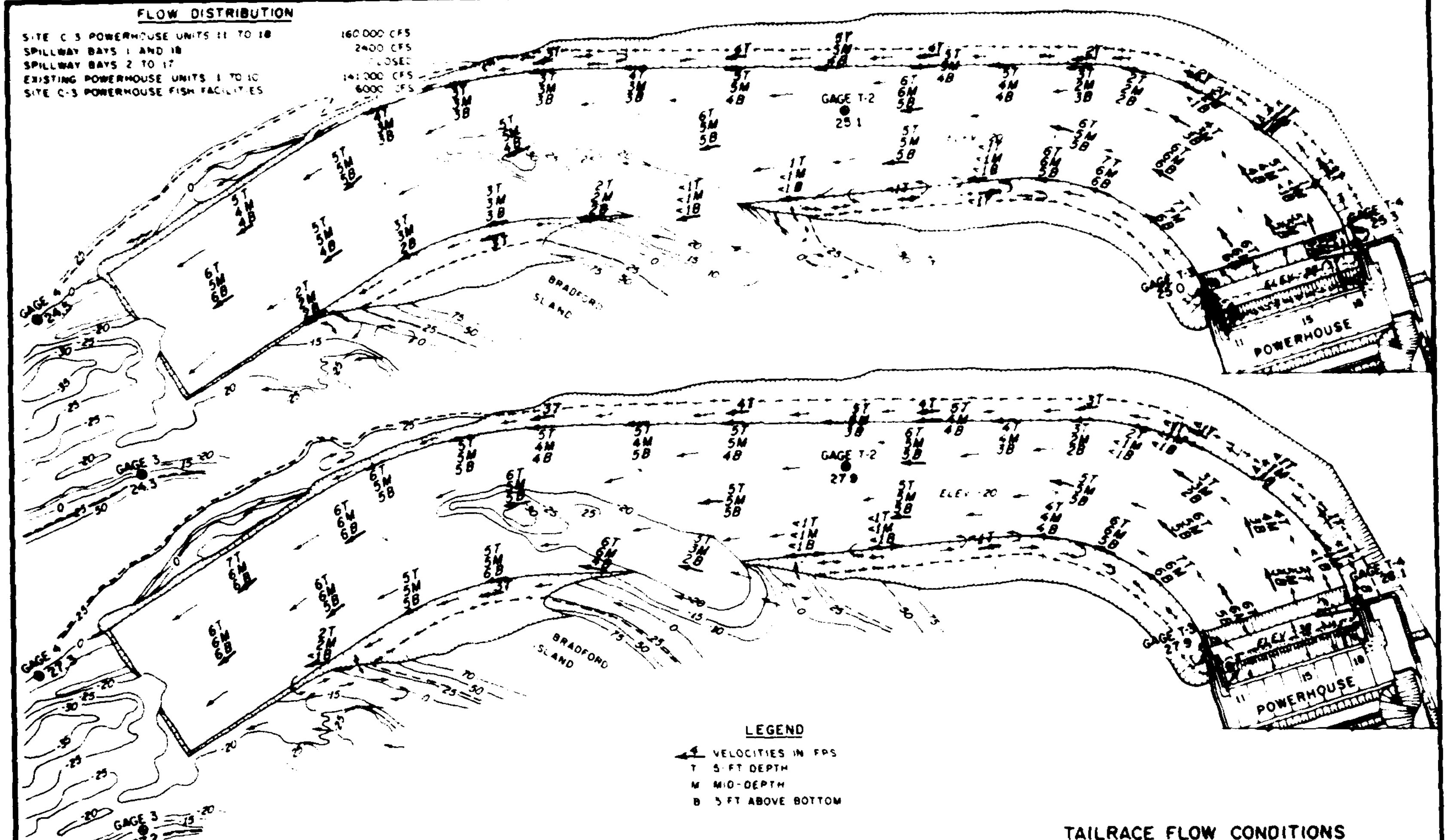

FLOW DISTRIBUTION
SITE C-3 POWERHOUSE UNITS 11 TO 18 160 000 CFS
SPILLWAY BAYS 1 AND 18 2 400 CFS
SPILLWAY BAYS 2 TO 17 CLOSED
EXISTING POWERHOUSE UNITS 1, 2, 9 AND 10 40 000 CFS
SITE C-3 POWERHOUSE FISH FACILITIES 6 000 CFS
GAGE T-2
19.3
GAGE T-4
19.7
GAGE T-3
19.4
GAGE 4
18.8
GAGE 3
18.8
ELEV -20
ELEV -38
BRADFORD ISLAND
POWERHOUSE
GAGE T-2
19.3
GAGE T-4
19.4
GAGE T-3
19.3
LEGEND
VELOCITIES IN FPS
T 5 FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
FLOW DISTRIBUTION
SITE C-3 POWERHOUSE UNITS 11 TO 18 100 000 CFS
SPILLWAY BAYS 1 AND 18 2 400 CFS
SPILLWAY BAYS 2 TO 17 CLOSED
EXISTING POWERHOUSE UNITS 1 TO 10 100 000 CFS
SITE C-3 POWERHOUSE FISH FACILITIES 6 000 CFS
SCALE
0 500 1000 FT
TAILRACE FLOW CONDITIONS
SITE C-3 POWERHOUSE
PLAN C-6E TAILRACE
RIVER DISCHARGE 208 400 CFS

PLATE 37



LEGEND

- 4 VELOCITIES IN FPS
- T 5 FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM

FLOW DISTRIBUTION

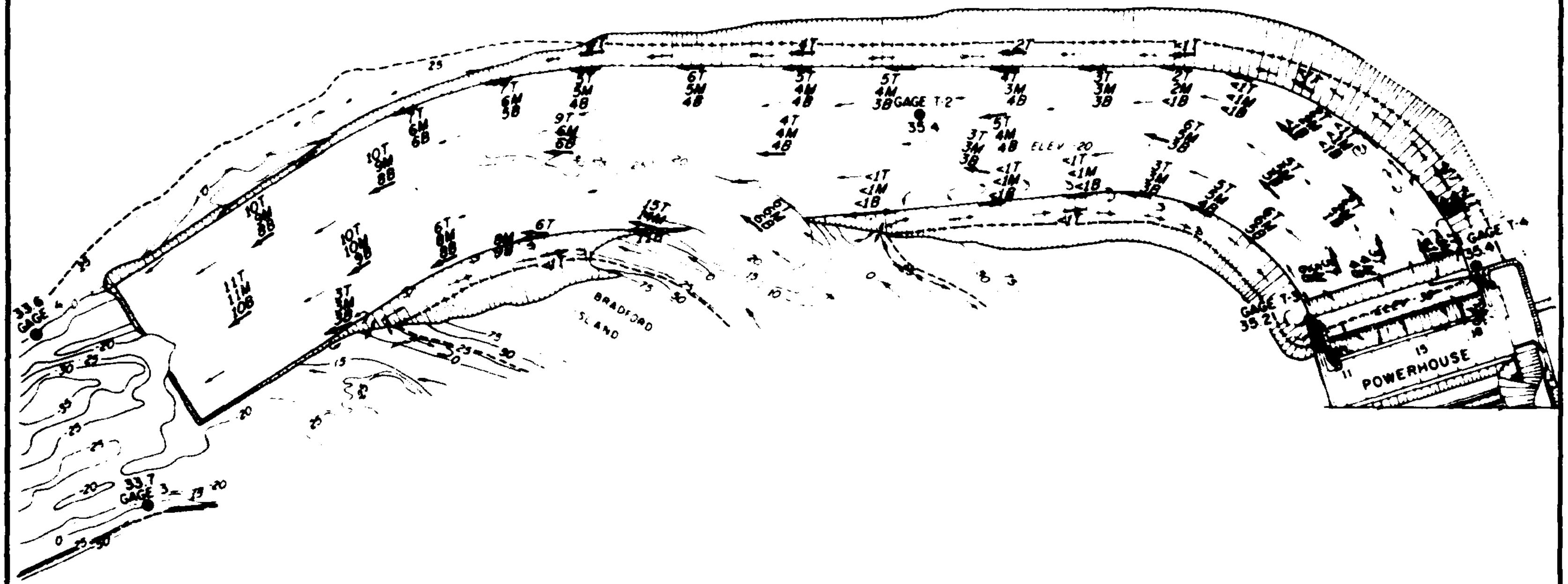
SITE C-3 POWERHOUSE UNITS 11 TO 18	160 000 CFS
SPILLWAY BAYS 1 AND 18	2400 CFS
SPILLWAY BAYS 2 TO 17	50 800 CFS
EXISTING POWERHOUSE UNITS 1 TO 10	141 000 CFS
SITE C-3 POWERHOUSE FISH FACILITIES	6000 CFS

SCALE

0 500 1000 FT

TAILRACE FLOW CONDITIONS
SITE C-3 POWERHOUSE
PLAN C-6E TAILRACE
RIVER DISCHARGES 309 400 AND 360 000 CFS

PLATE 38



FLOW DISTRIBUTION

SITE C-3 POWERHOUSE UNITS 11 TO 18	160 000 CFS
SPILLWAY BAYS 1 AND 18	2 400 CFS
SPILLWAY BAYS 2 TO 17	199 600 CFS
EXISTING POWERHOUSE UNITS 1 TO 10	142 000 CFS
SITE C-3 POWERHOUSE FISH FACILITIES	6 000 CFS

LEGEND

- 4 VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM

SCALE

0 500 1000 FT

TAILRACE FLOW CONDITIONS

SITE C-3 POWERHOUSE

PLAN C-6E TAILRACE

RIVER DISCHARGE 510 000 CFS

PLATE 39

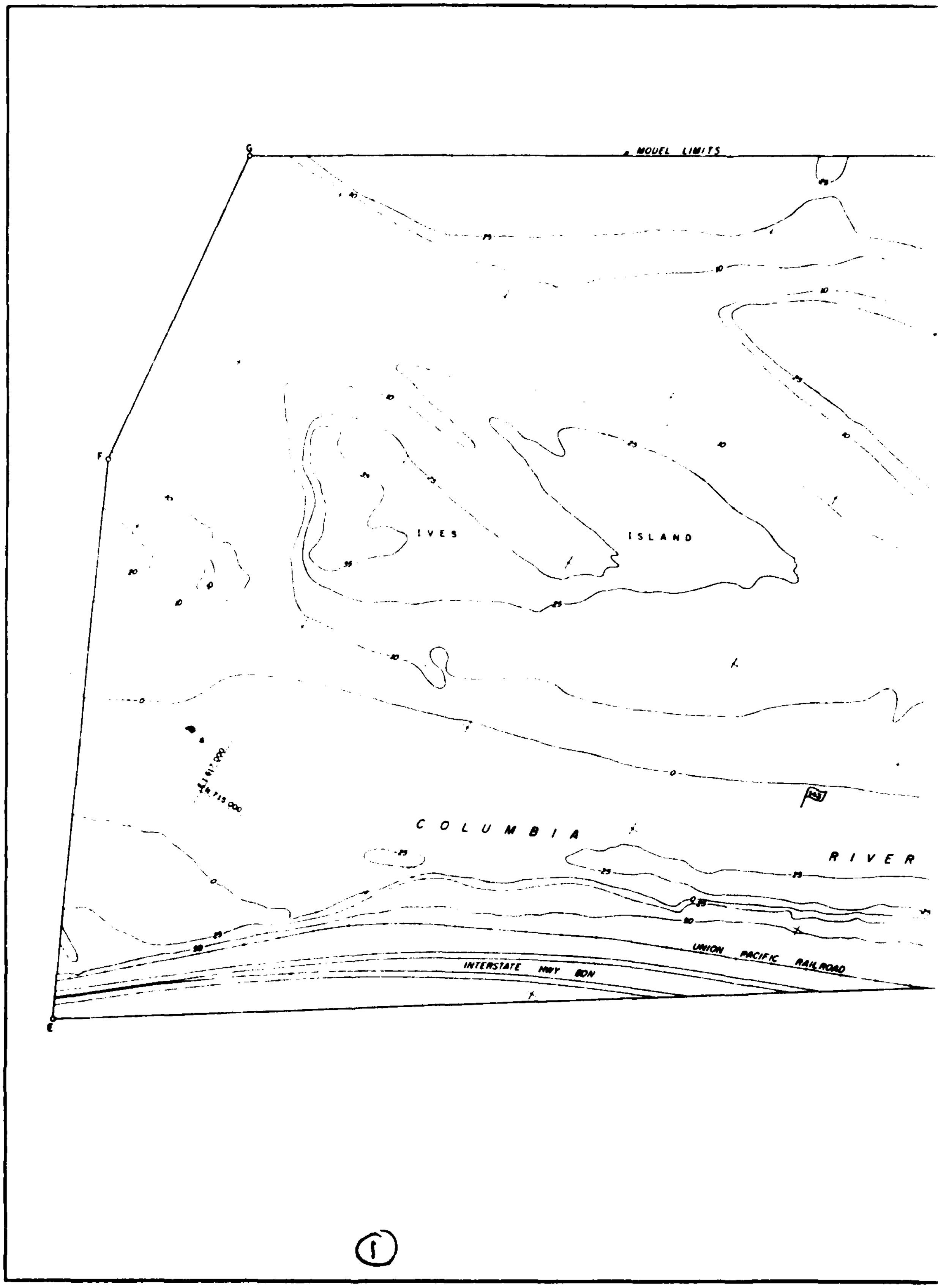
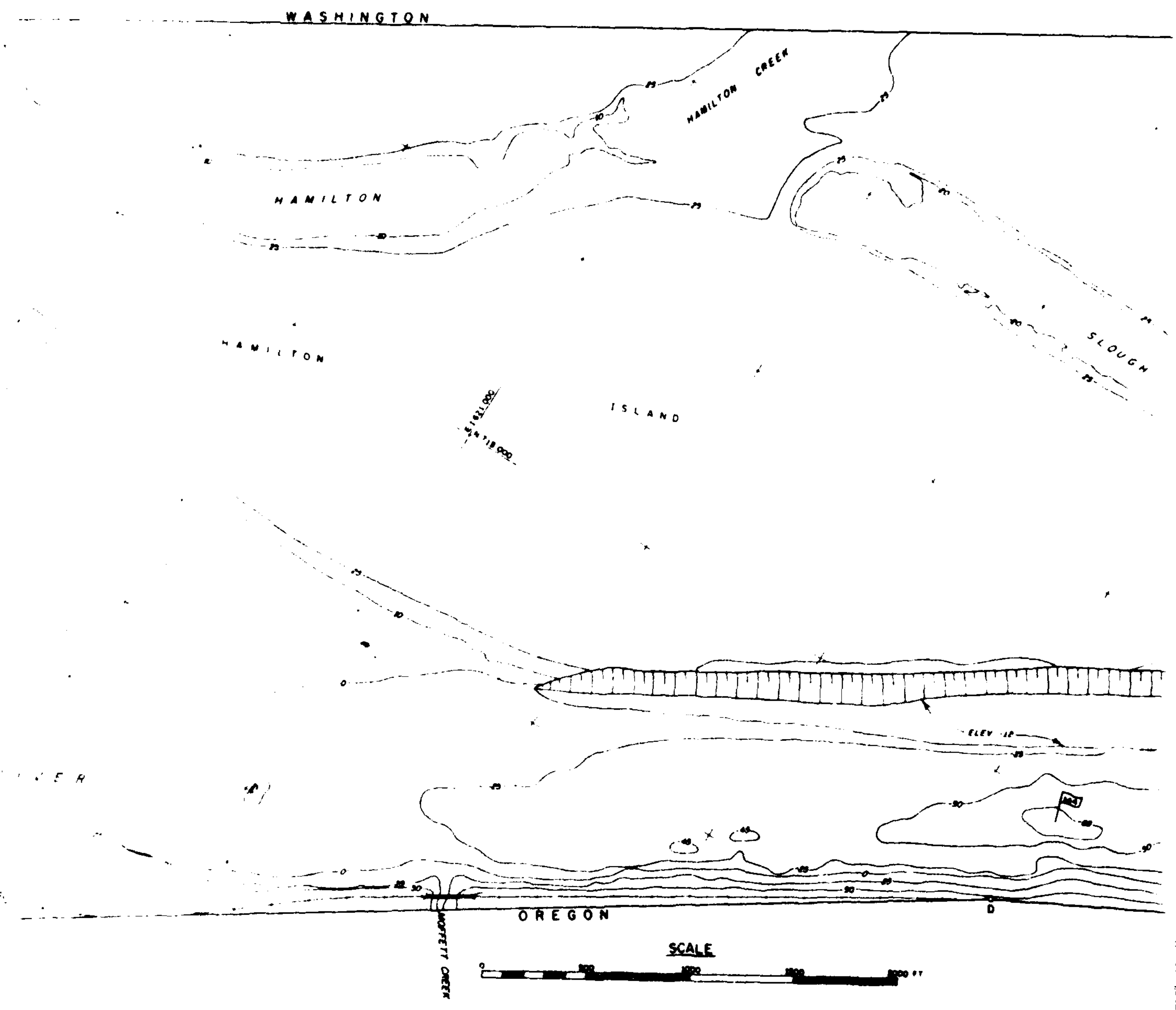
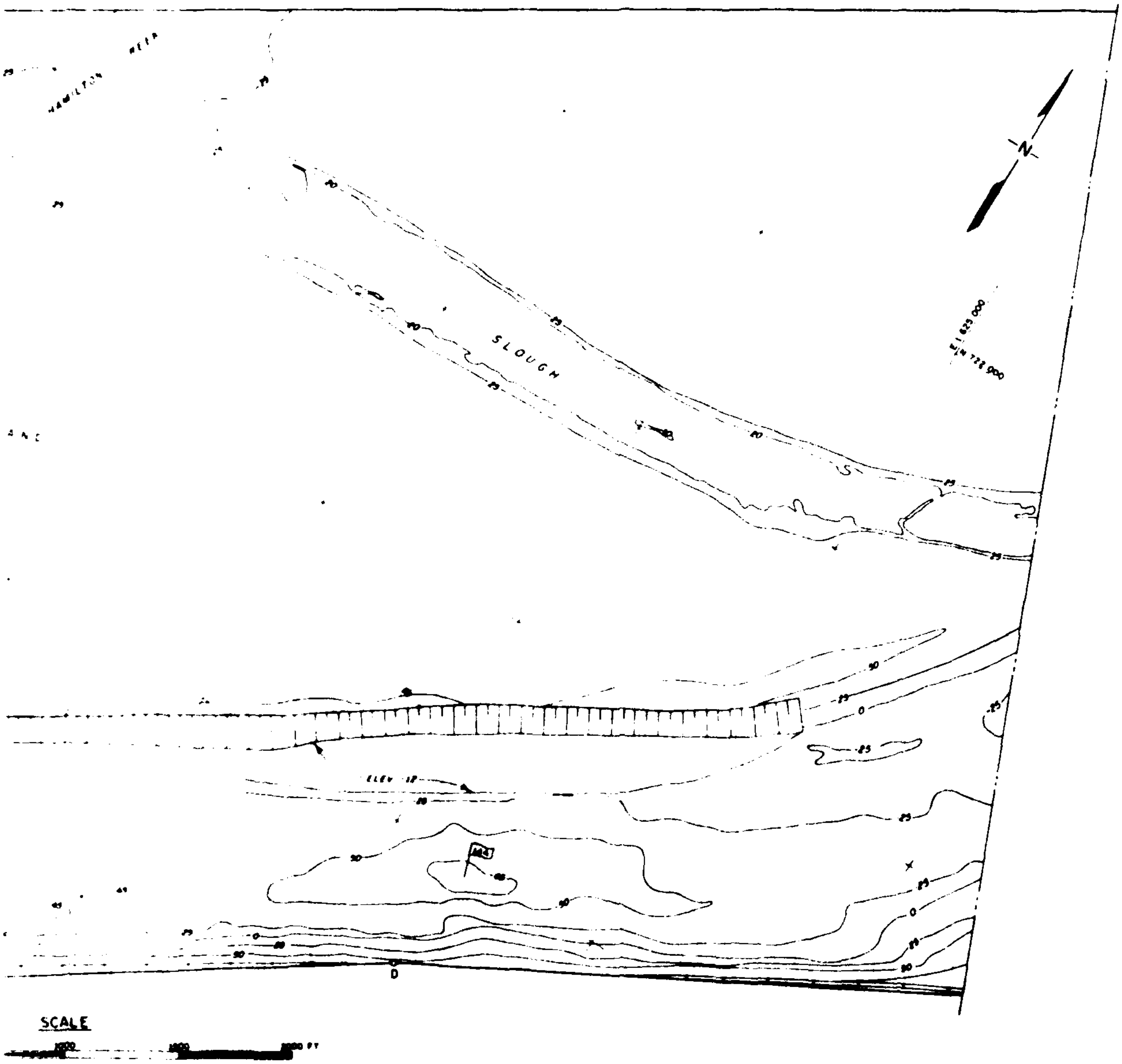

MODEL LIMITS
G
F
E
IVES ISLAND
COLUMBIA RIVER
UNION PACIFIC RAILROAD
INTERSTATE HWY 80N

Plate 40



WASHINGTON
HAMILTON CREEK
HAMILTON
HAMILTON
ISLAND
SLOUGH
ELEV 12
OREGON
MOFFETT CREEK
SCALE
0
500
1000
1500
2000 FT

3



HAMILTON ISLAND
EXISTING CONDITION
3 of 3

PLATE 40

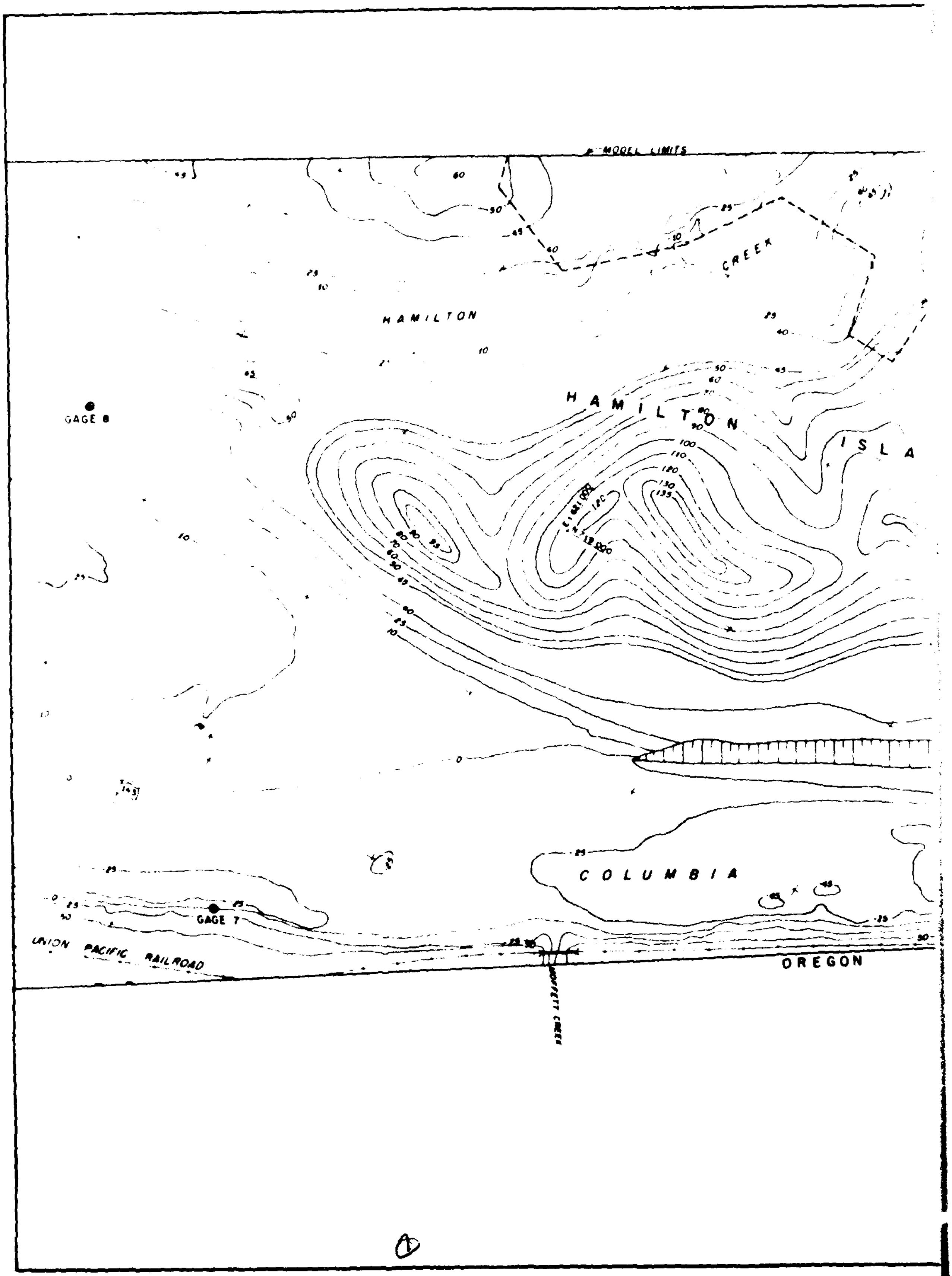
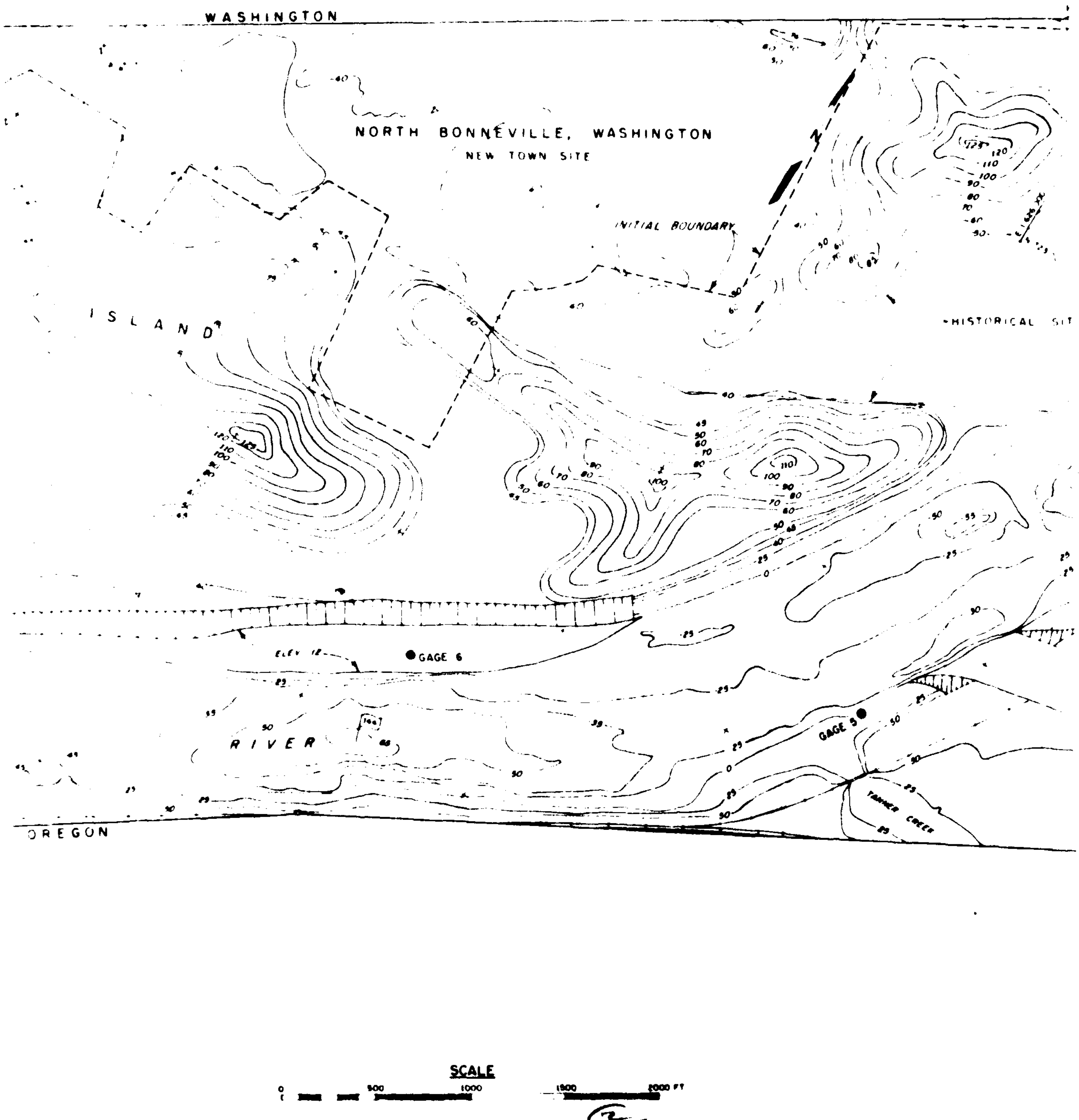
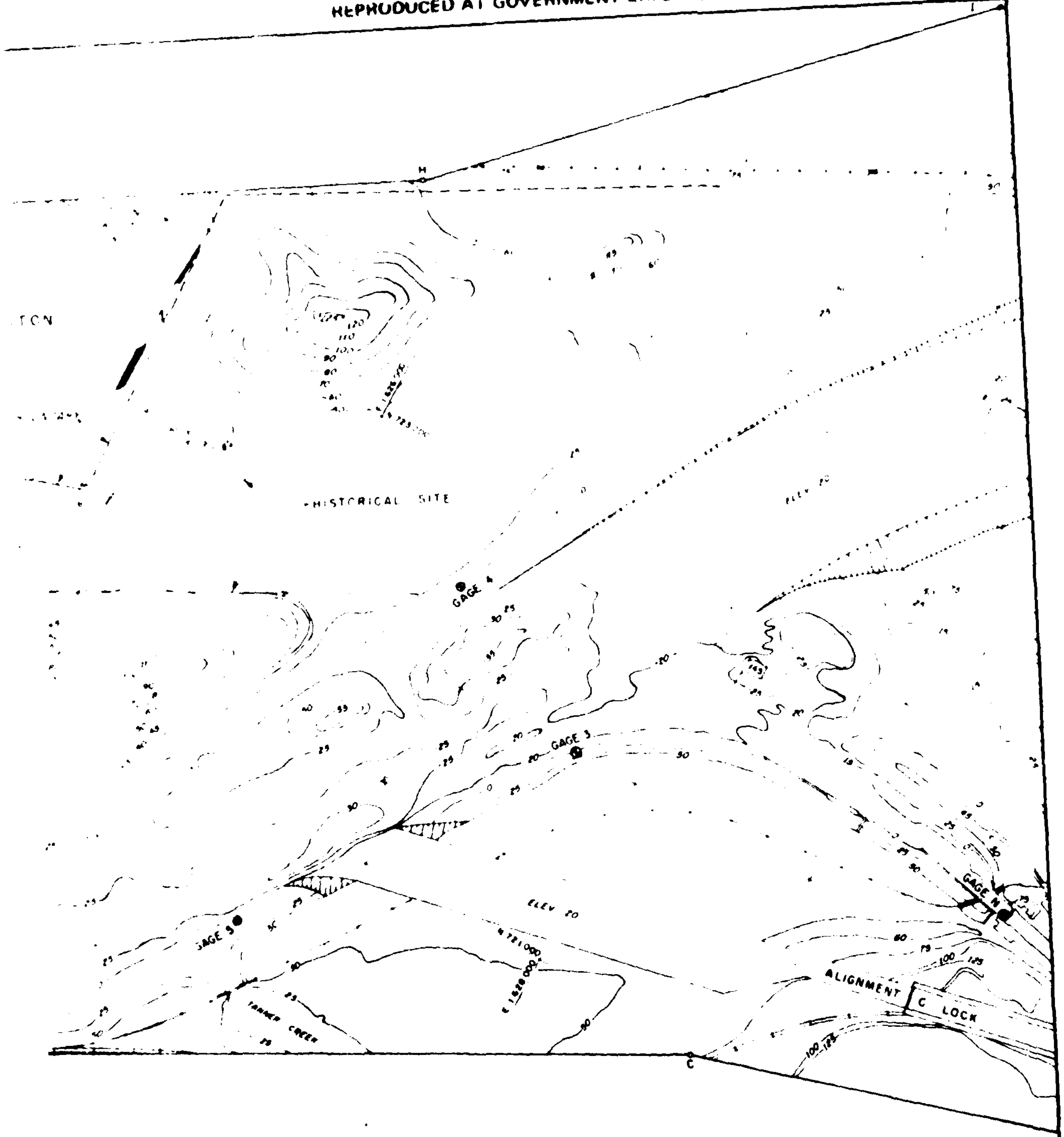

MODEL LIMITS
CREEK
HAMILTON
GAGE 8
HAMILTON ISLA
COLUMBIA
GAGE 7
UNION PACIFIC RAILROAD
OREGON

Plate 41

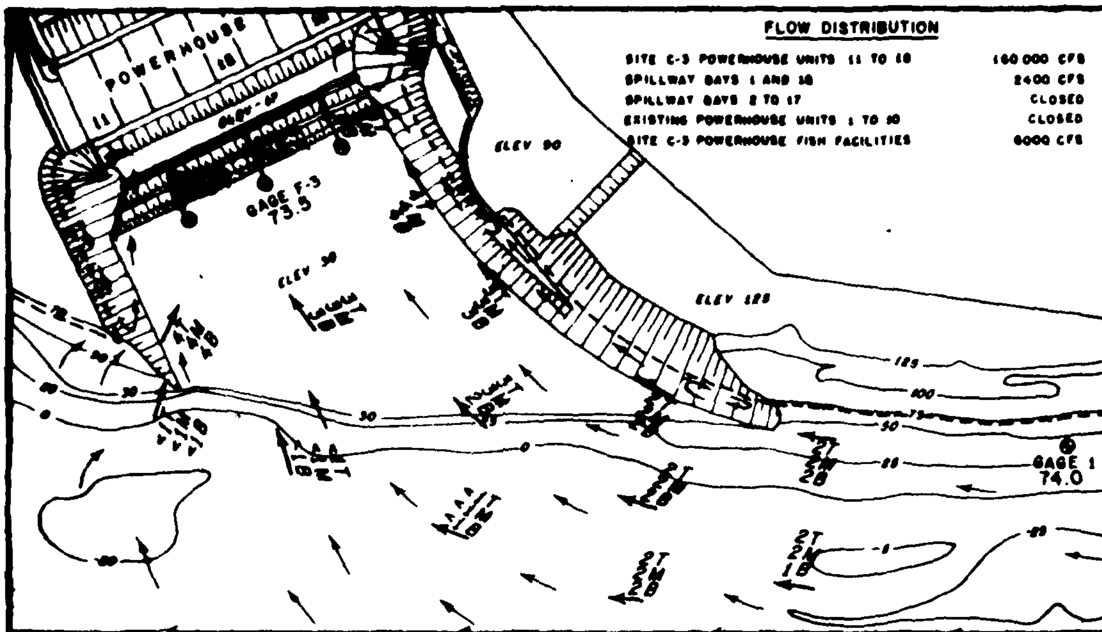

WASHINGTON
NORTH BONNEVILLE, WASHINGTON
NEW TOWN SITE
INITIAL BOUNDARY
ISLAND
HISTORICAL SIT
GAGE 6
ELEV 12
RIVER
GAGE 5
TANNER CREEK
OREGON
SCALE
0
500
1000
1500
2000 FT



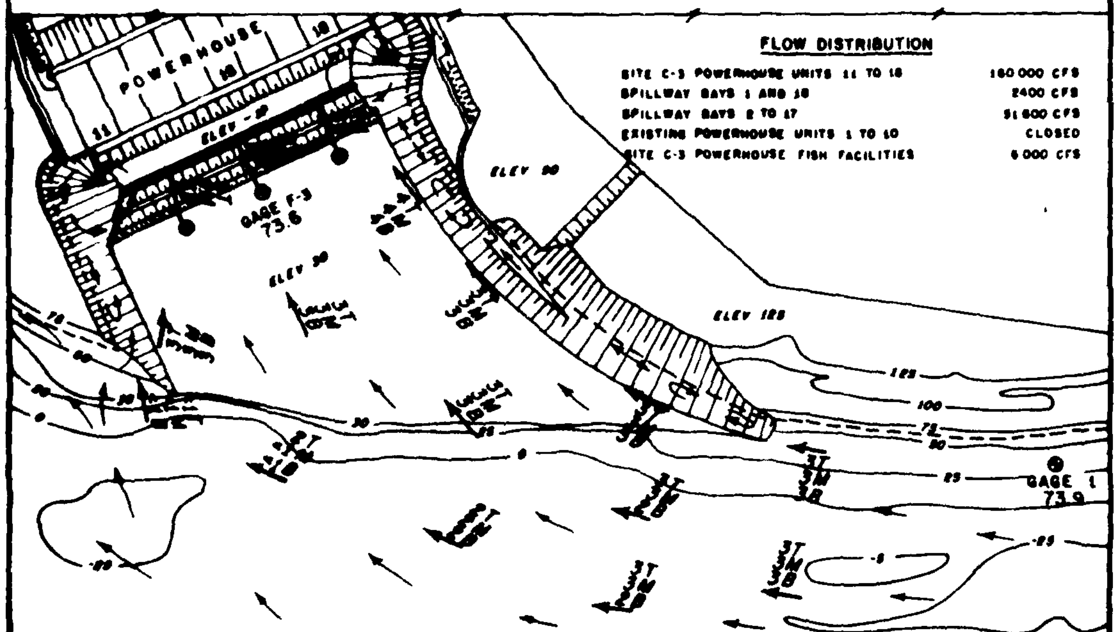
HAMILTON ISLAND FILL

3 of 3

PLATE 41



RIVER DISCHARGE 168 400 CFS



RIVER DISCHARGE 220 000 CFS

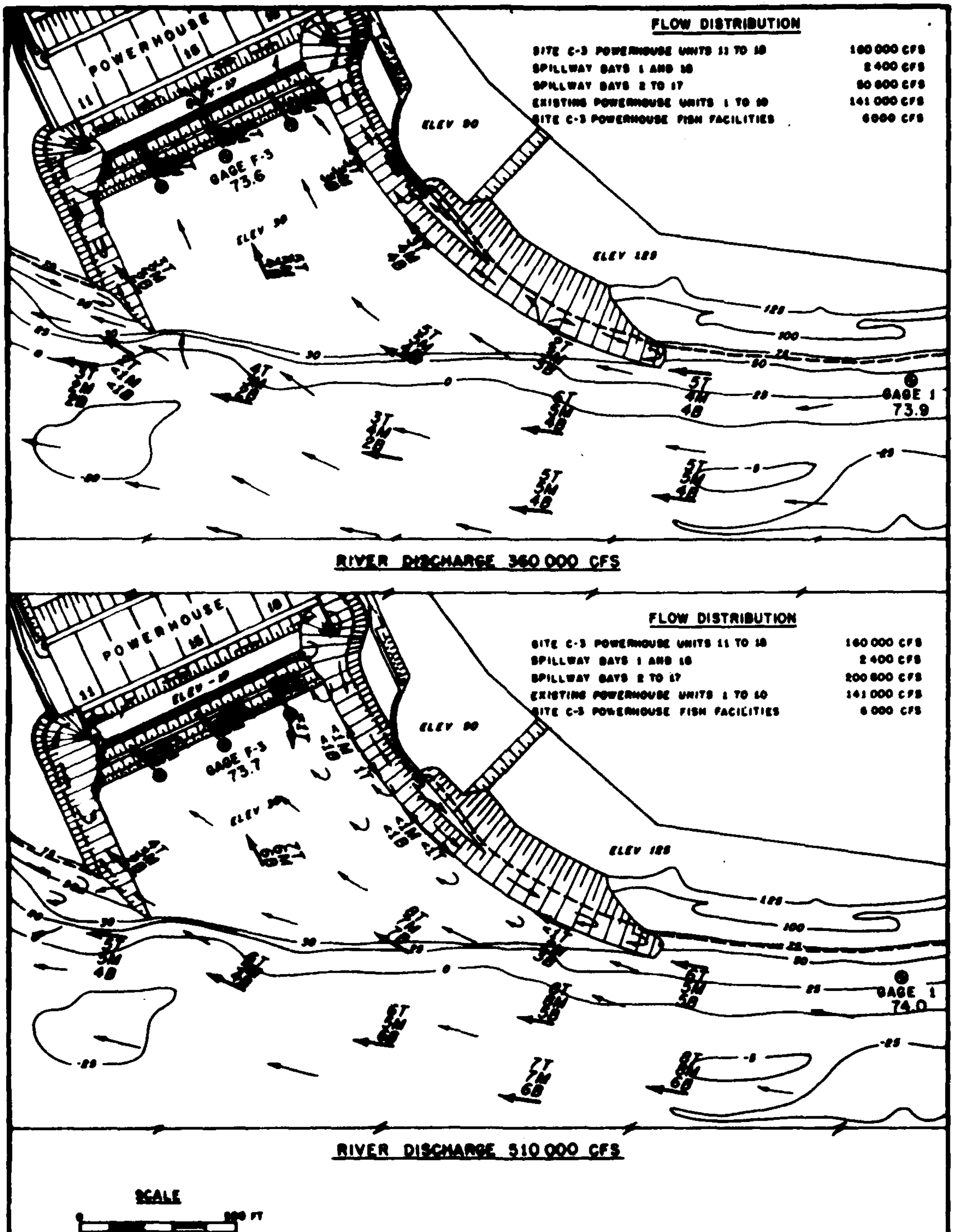
SCALE

LEGEND

VELOCITIES IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 3 FT ABOVE BOTTOM

PLAN C-1 APPROACH
APPROACH FLOW CONDITIONS
SITE C-3 POWERHOUSE
RIVER DISCHARGES 168 400 AND 220 000 CFS

PLATE 42



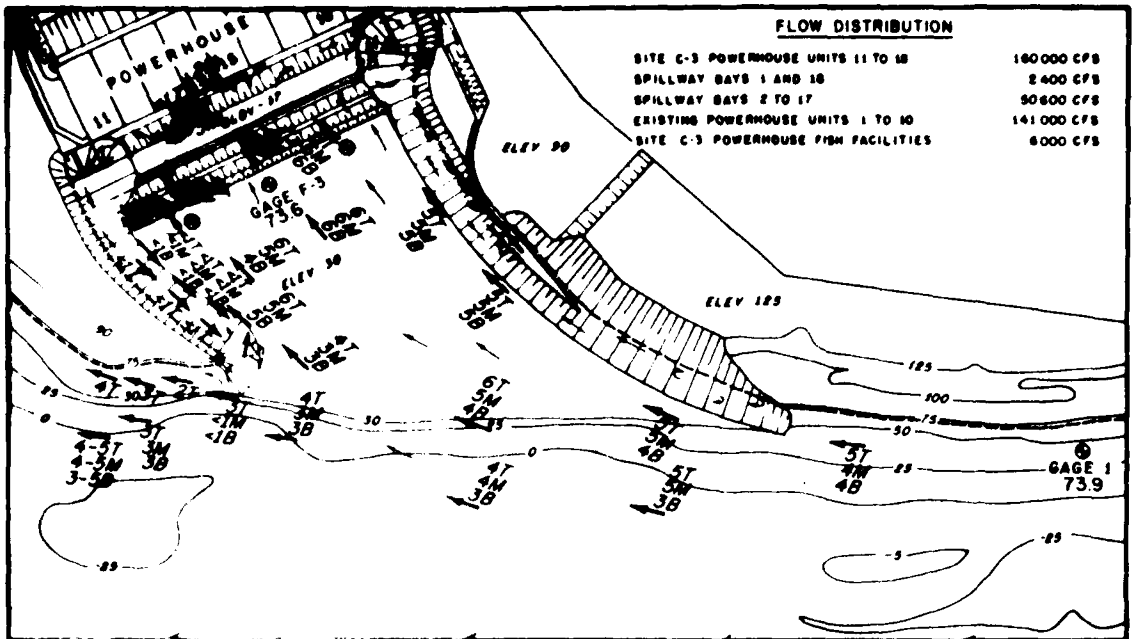
PLAN C-1 APPROACH

APPROACH FLOW CONDITIONS

SITE C-3 POWERHOUSE

RIVER DISCHARGES 360000 AND 510000 CFS

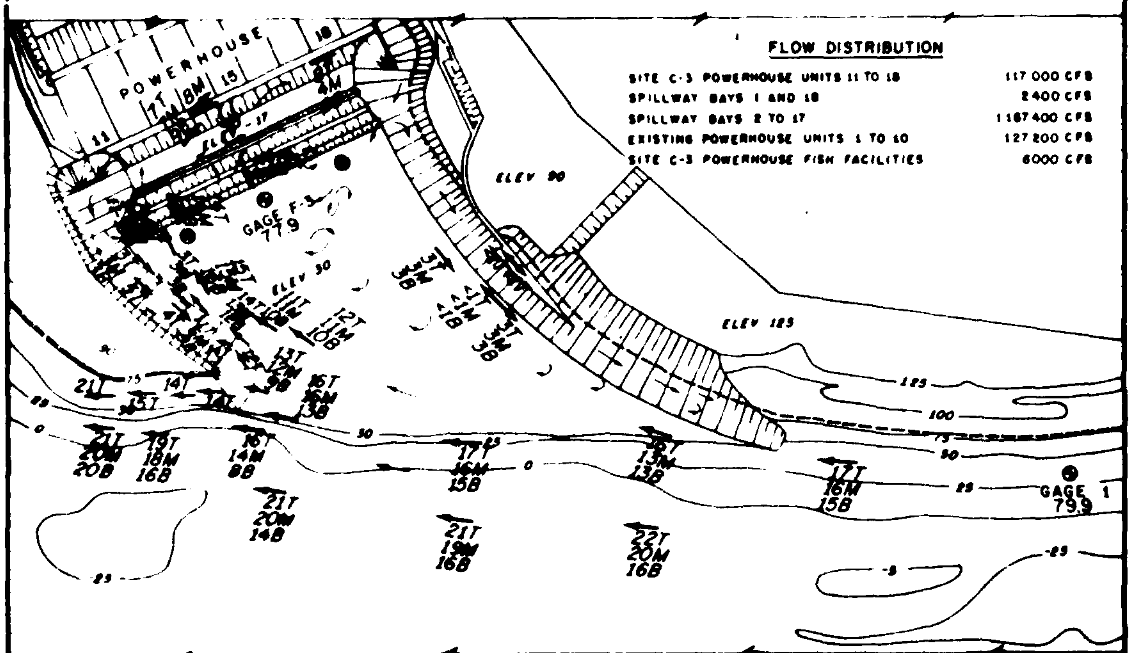
PLATE 43



FLOW DISTRIBUTION

SITE C-3 POWERHOUSE UNITS 11 TO 18	160 000 CFS
SPILLWAY BAYS 1 AND 18	2 400 CFS
SPILLWAY BAYS 2 TO 17	50 600 CFS
EXISTING POWERHOUSE UNITS 1 TO 10	141 000 CFS
SITE C-3 POWERHOUSE FISH FACILITIES	6000 CFS

RIVER DISCHARGE 360 000 CFS



FLOW DISTRIBUTION

SITE C-3 POWERHOUSE UNITS 11 TO 18	117 000 CFS
SPILLWAY BAYS 1 AND 18	2 400 CFS
SPILLWAY BAYS 2 TO 17	1 167 400 CFS
EXISTING POWERHOUSE UNITS 1 TO 10	127 200 CFS
SITE C-3 POWERHOUSE FISH FACILITIES	6000 CFS

RIVER DISCHARGE 1,420,000 CFS

PLAN C-2 APPROACH
PLAN B TRAINING WALL

SCALE

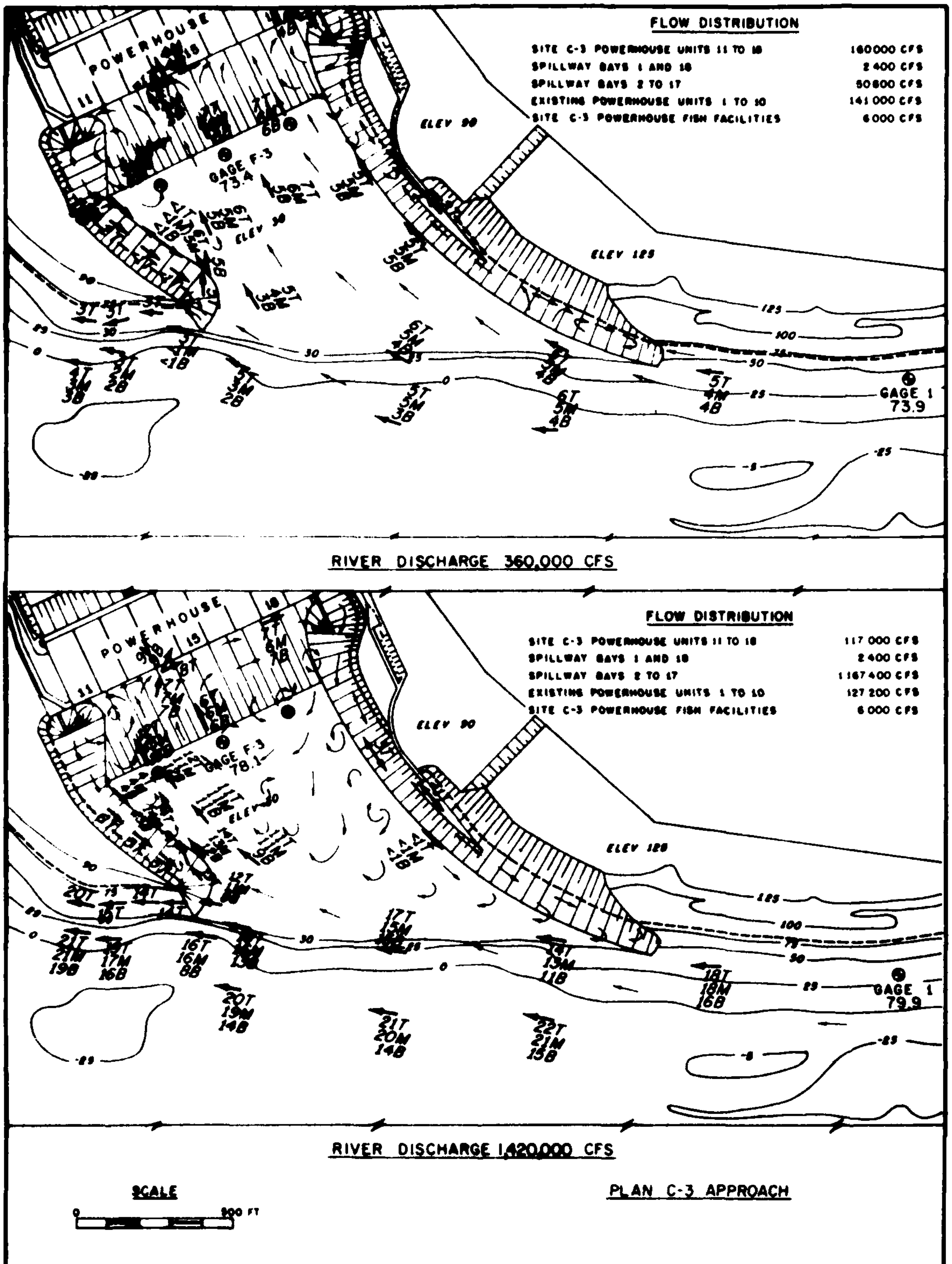
0 — 800 FT

LEGEND

4 VELOCITIES IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
SURFACE FLOW DIRECTION

APPROACH FLOW CONDITIONS
SITE C-3 POWERHOUSE
RIVER DISCHARGES 360 000 AND 1,420,000 CFS

PLATE 44

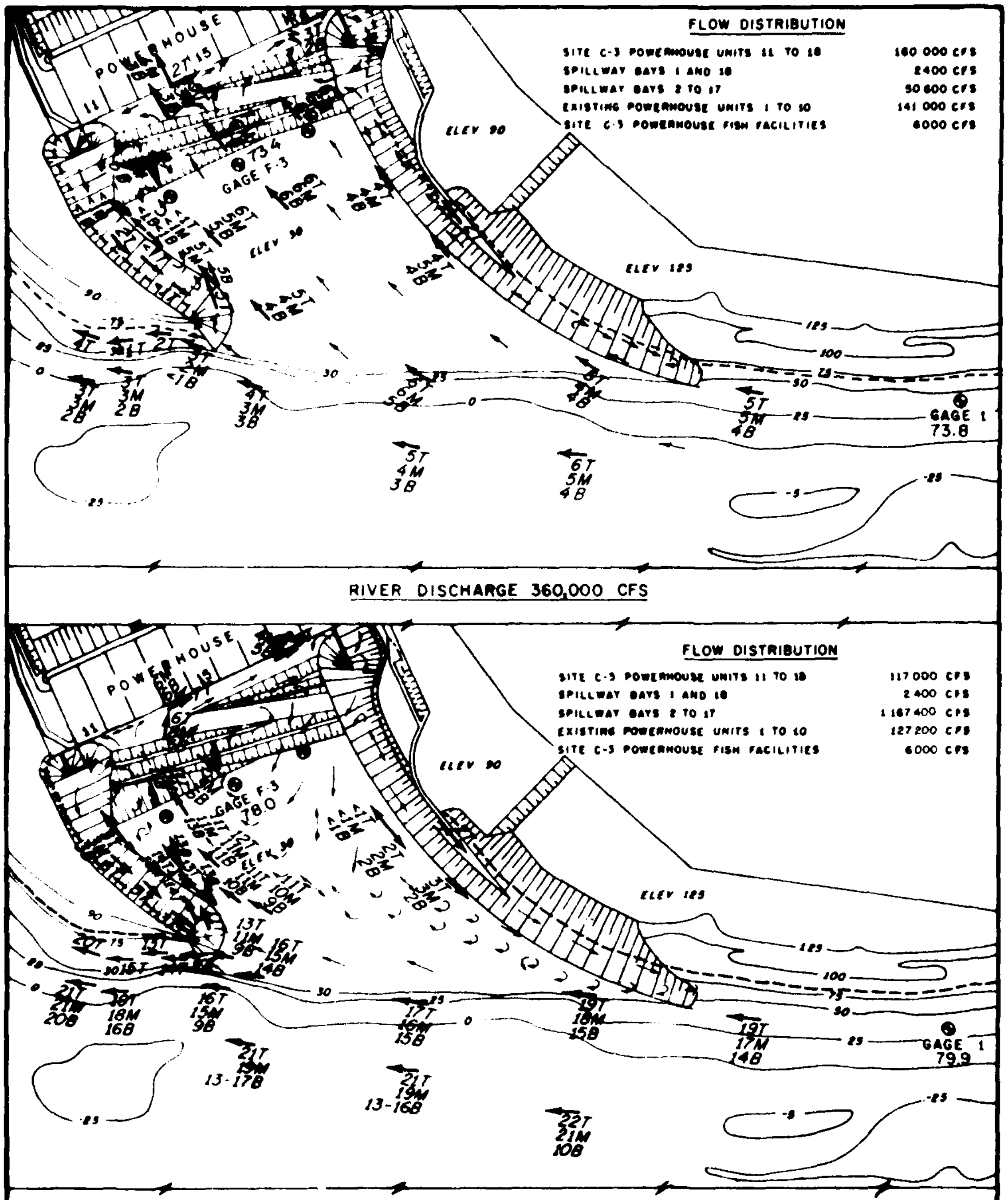


APPROACH FLOW CONDITIONS

SITE C-3 POWERHOUSE

RIVER DISCHARGES 360,000 AND 1,420,000 CFS

PLATE 45



LEGEND

- 4 VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- SURFACE FLOW DIRECTION

SCALE

0 — 500 FT

PLAN C-4 APPROACH

APPROACH FLOW CONDITIONS

SITE C-3 POWERHOUSE

RIVER DISCHARGES 360,000 AND 1,420,000 CFS

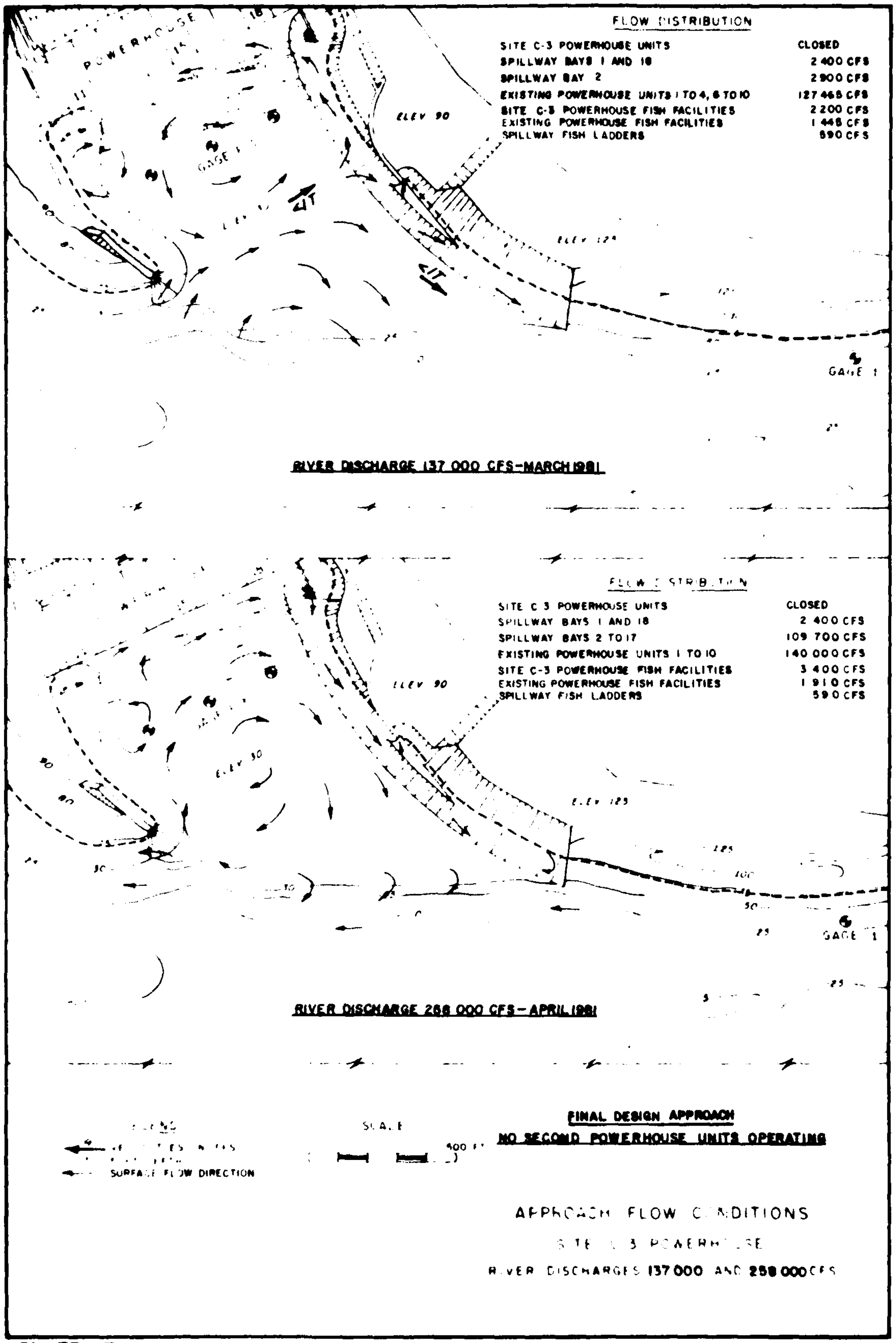
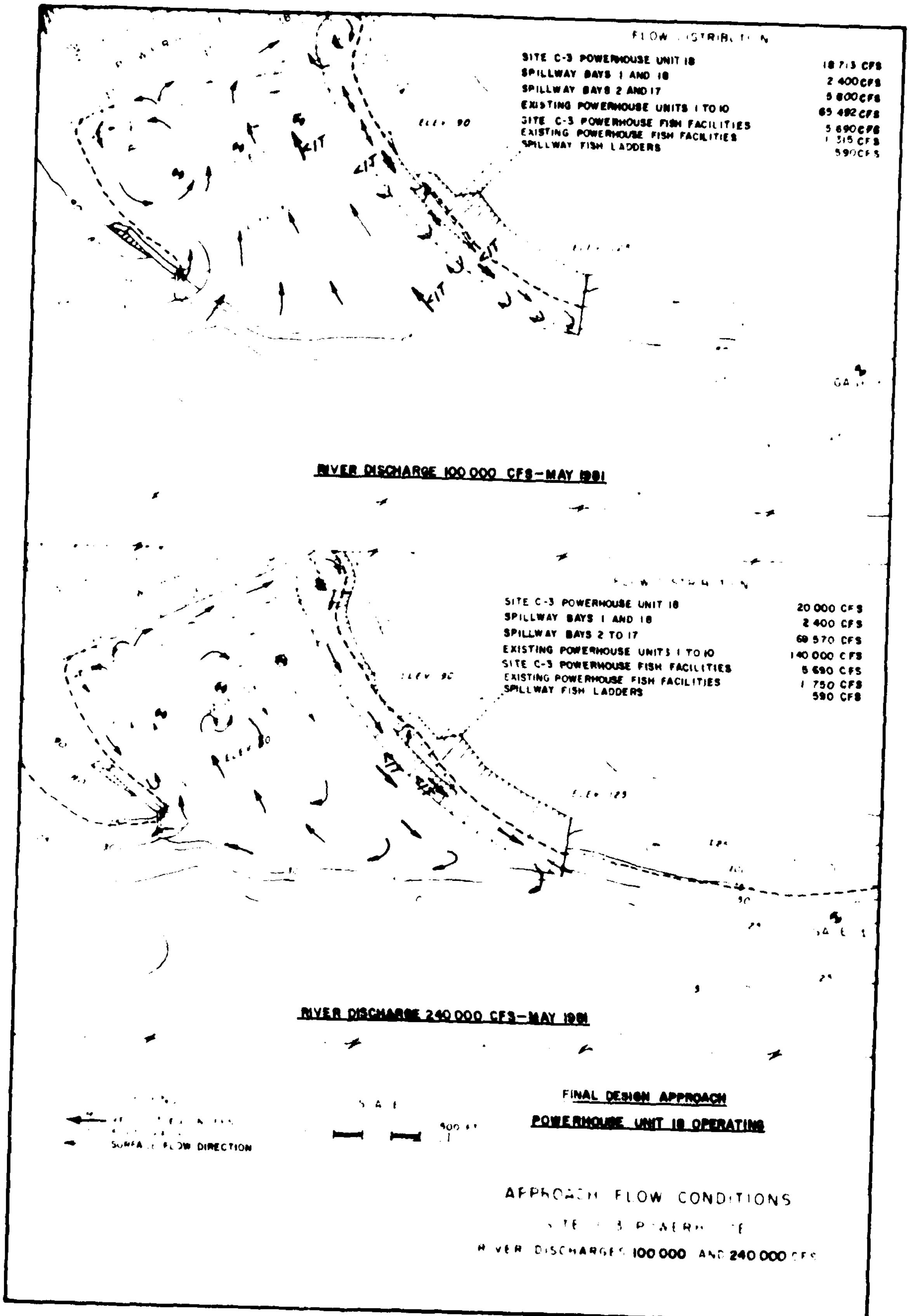
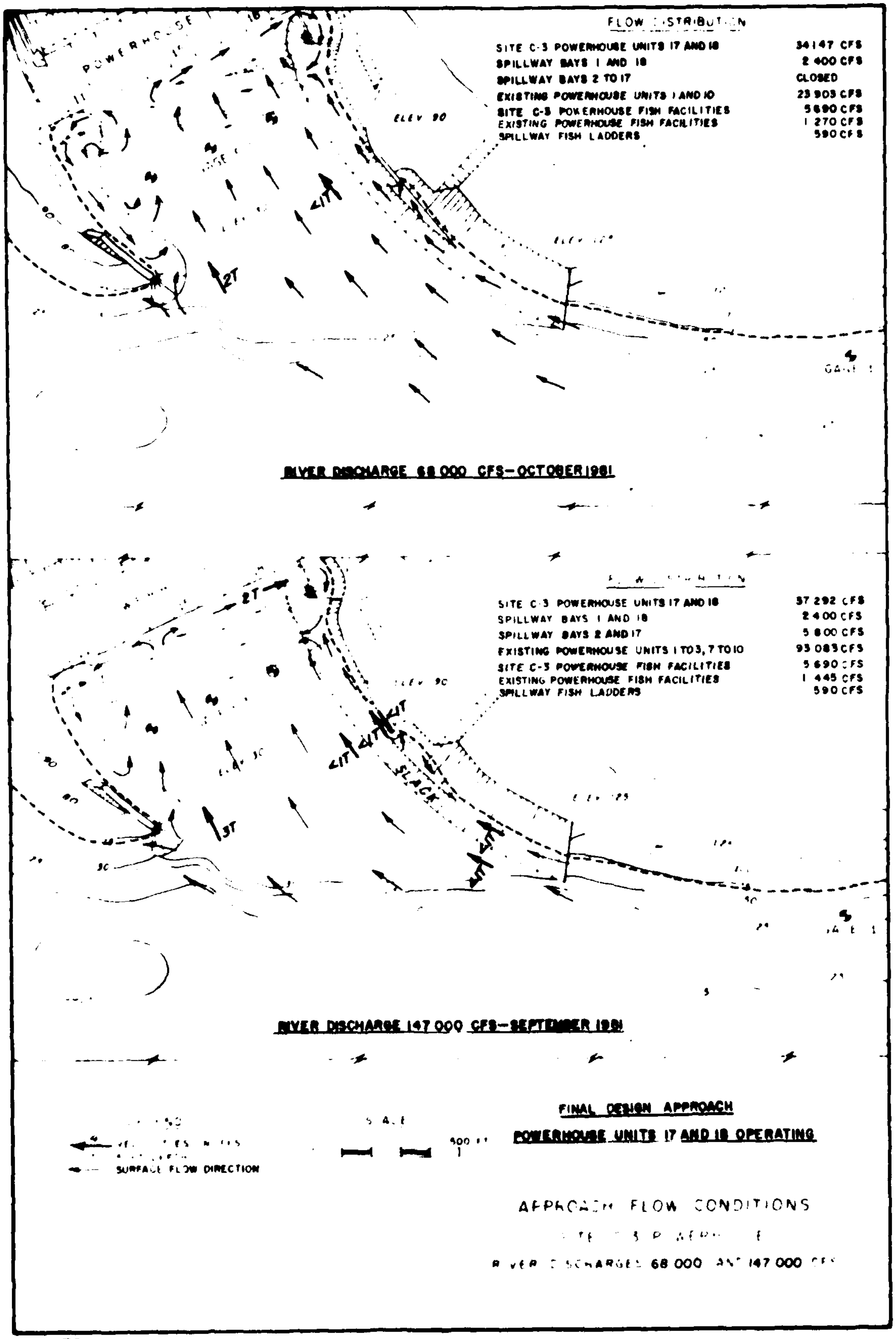

FLOW DISTRIBUTION
SITE C-3 POWERHOUSE UNITS CLOSED
SPILLWAY BAYS 1 AND 18 2 400 CFS
SPILLWAY BAY 2 2 900 CFS
EXISTING POWERHOUSE UNITS 1 TO 4, 6 TO 10 127 465 CFS
SITE C-3 POWERHOUSE FISH FACILITIES 2 200 CFS
EXISTING POWERHOUSE FISH FACILITIES 1 445 CFS
SPILLWAY FISH LADDERS 590 CFS
ELEV 90
GAGE 1
RIVER DISCHARGE 137 000 CFS-MARCH 1981
SITE C-3 POWERHOUSE UNITS CLOSED
SPILLWAY BAYS 1 AND 18 2 400 CFS
SPILLWAY BAYS 2 TO 17 109 700 CFS
EXISTING POWERHOUSE UNITS 1 TO 10 140 000 CFS
SITE C-3 POWERHOUSE FISH FACILITIES 3 400 CFS
EXISTING POWERHOUSE FISH FACILITIES 1 910 CFS
SPILLWAY FISH LADDERS 590 CFS
ELEV 90
ELEV 30
ELEV 125
RIVER DISCHARGE 268 000 CFS-APRIL 1981
SURFACE FLOW DIRECTION
SCALE
500 FT
FINAL DESIGN APPROACH
NO SECOND POWERHOUSE UNITS OPERATING
APPROACH FLOW CONDITIONS
RIVER DISCHARGES 137 000 AND 268 000 CFS

PLATE 47



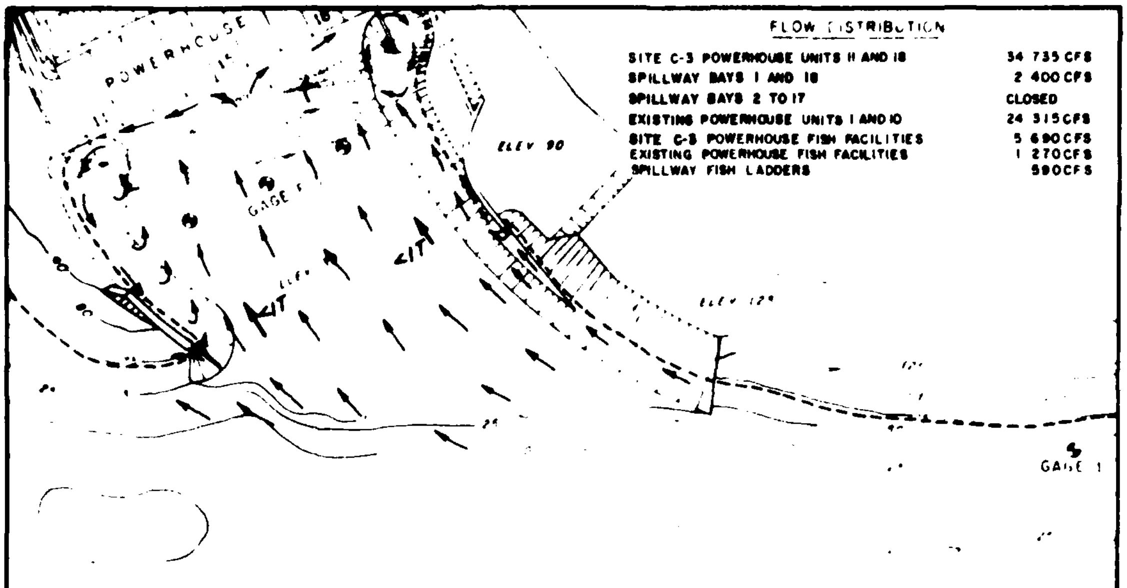
SITE C-3 POWERHOUSE UNIT 18 18 713 CFS
SPILLWAY BAYS 1 AND 18 2 400 CFS
SPILLWAY BAYS 2 AND 17 5 800 CFS
EXISTING POWERHOUSE UNITS 1 TO 10 65 492 CFS
SITE C-3 POWERHOUSE FISH FACILITIES 5 690 CFS
EXISTING POWERHOUSE FISH FACILITIES 1 315 CFS
SPILLWAY FISH LADDERS 590 CFS
RIVER DISCHARGE 100 000 CFS–MAY 1981
SITE C-3 POWERHOUSE UNIT 18 20 000 CFS
SPILLWAY BAYS 1 AND 18 2 400 CFS
SPILLWAY BAYS 2 TO 17 69 570 CFS
EXISTING POWERHOUSE UNITS 1 TO 10 140 000 CFS
SITE C-3 POWERHOUSE FISH FACILITIES 5 690 CFS
EXISTING POWERHOUSE FISH FACILITIES 1 750 CFS
SPILLWAY FISH LADDERS 590 CFS
RIVER DISCHARGE 240 000 CFS–MAY 1981
SURFACE FLOW DIRECTION
FINAL DESIGN APPROACH
POWERHOUSE UNIT 18 OPERATING
APPROACH FLOW CONDITIONS

PLATE 48



POWERHOUSE
ELEV 90
SITE C-3 POWERHOUSE UNITS 17 AND 18 34 147 CFS
SPILLWAY BAYS 1 AND 18 2 400 CFS
SPILLWAY BAYS 2 TO 17 CLOSED
EXISTING POWERHOUSE UNITS 1 AND 10 23 903 CFS
SITE C-3 POWERHOUSE FISH FACILITIES 5 690 CFS
EXISTING POWERHOUSE FISH FACILITIES 1 270 CFS
SPILLWAY FISH LADDERS 590 CFS
RIVER DISCHARGE 68 000 CFS—OCTOBER 1981
SITE C-3 POWERHOUSE UNITS 17 AND 18 37 292 CFS
SPILLWAY BAYS 1 AND 18 2 400 CFS
SPILLWAY BAYS 2 AND 17 5 800 CFS
EXISTING POWERHOUSE UNITS 1 TO 3, 7 TO 10 93 083 CFS
SITE C-3 POWERHOUSE FISH FACILITIES 5 690 CFS
EXISTING POWERHOUSE FISH FACILITIES 1 445 CFS
SPILLWAY FISH LADDERS 590 CFS
SLACK
RIVER DISCHARGE 147 000 CFS—SEPTEMBER 1981
SURFACE FLOW DIRECTION
500 FT
FINAL DESIGN APPROACH
POWERHOUSE UNITS 17 AND 18 OPERATING
APPROACH FLOW CONDITIONS
RIVER DISCHARGES 68 000 AND 147 000 CFS

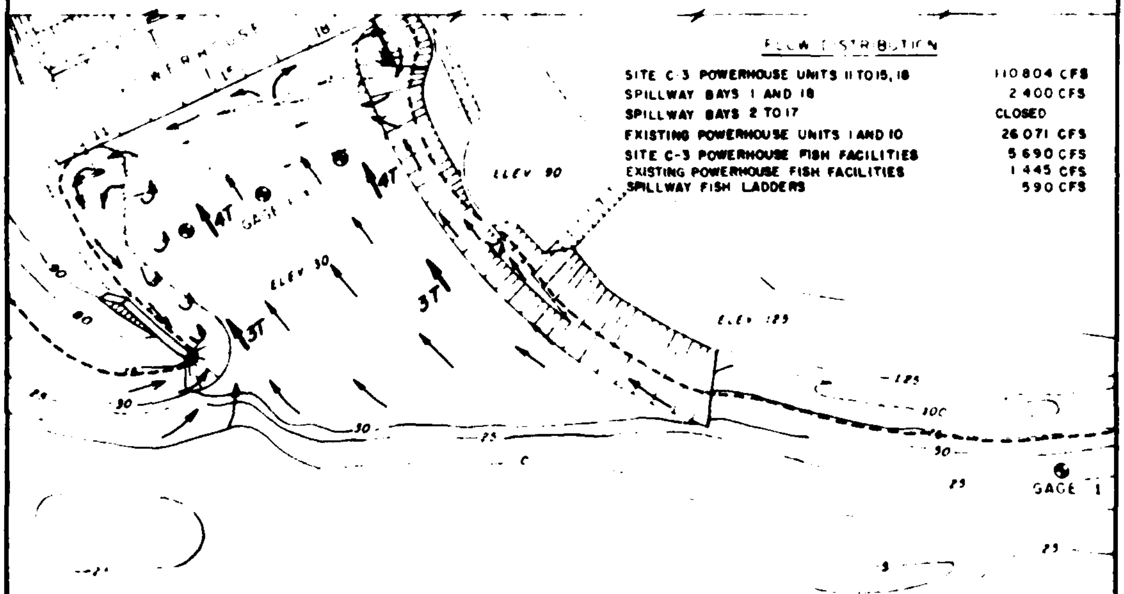
PLATE 49



FLOW DISTRIBUTION

SITE C-3 POWERHOUSE UNITS 11 AND 18	34 735 CFS
SPILLWAY BAYS 1 AND 18	2 400 CFS
SPILLWAY BAYS 2 TO 17	CLOSED
EXISTING POWERHOUSE UNITS 1 AND 10	24 315 CFS
SITE C-3 POWERHOUSE FISH FACILITIES	5 690 CFS
EXISTING POWERHOUSE FISH FACILITIES	1 270 CFS
SPILLWAY FISH LADDERS	590 CFS

RIVER DISCHARGE 69 000 CFS—SEPTEMBER 1982



FLOW DISTRIBUTION

SITE C-3 POWERHOUSE UNITS 11 TO 15, 18	110 804 CFS
SPILLWAY BAYS 1 AND 18	2 400 CFS
SPILLWAY BAYS 2 TO 17	CLOSED
EXISTING POWERHOUSE UNITS 1 AND 10	26 071 CFS
SITE C-3 POWERHOUSE FISH FACILITIES	5 690 CFS
EXISTING POWERHOUSE FISH FACILITIES	1 445 CFS
SPILLWAY FISH LADDERS	590 CFS

RIVER DISCHARGE 147 000 CFS—SEPTEMBER 1982

LEGEND

VELOCITIES IN FPS 5 FT DEPTH

SURFACE FLOW DIRECTION

SCALE

0 500 FT

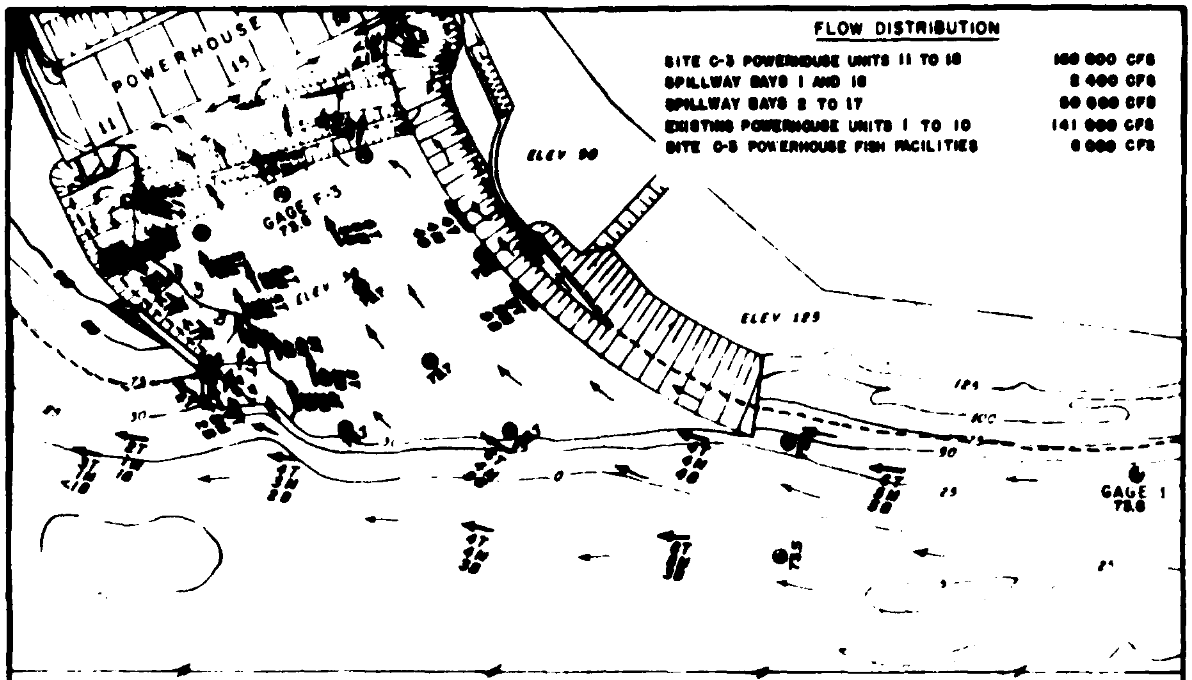
FINAL DESIGN APPROACH

POWERHOUSE UNITS 11 TO 18 OPERATING

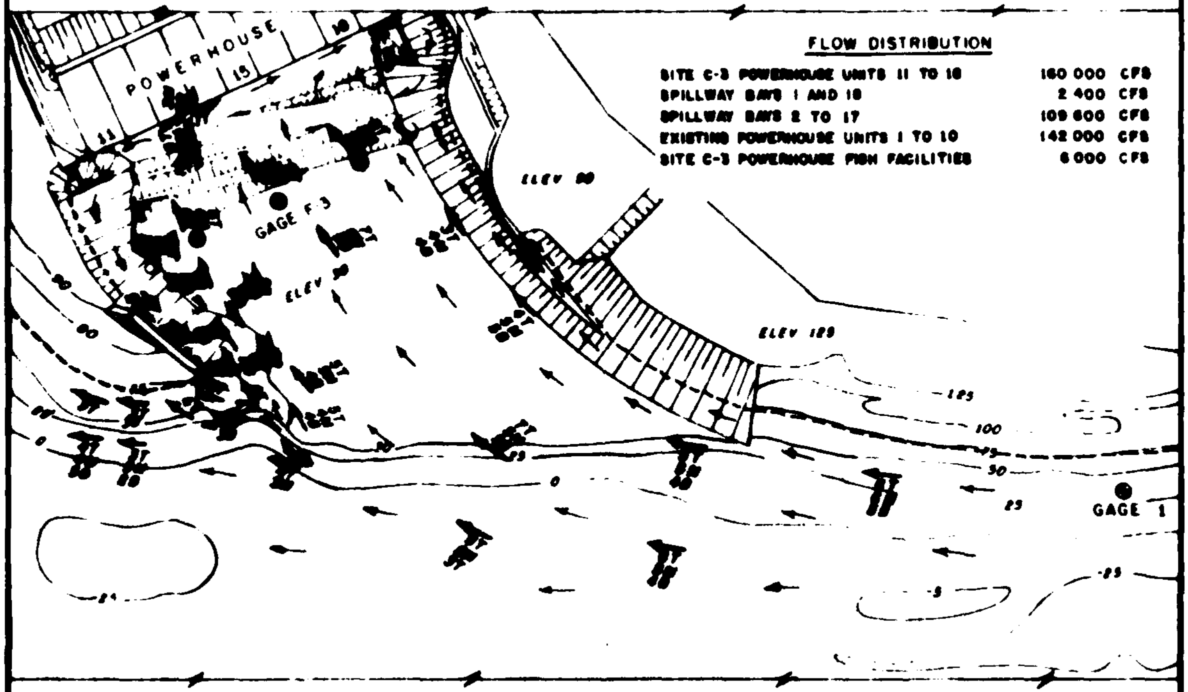
APPROACH FLOW CONDITIONS

SITE C-3 POWERHOUSE

RIVER DISCHARGES 69 000 AND 147 000 CFS



RIVER DISCHARGE 360 000 CFS



RIVER DISCHARGE 420 000 CFS

LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- SURFACE FLOW DIRECTION
- 73.8 WATER-SURFACE ELEVATION

SCALE

0 500 FT

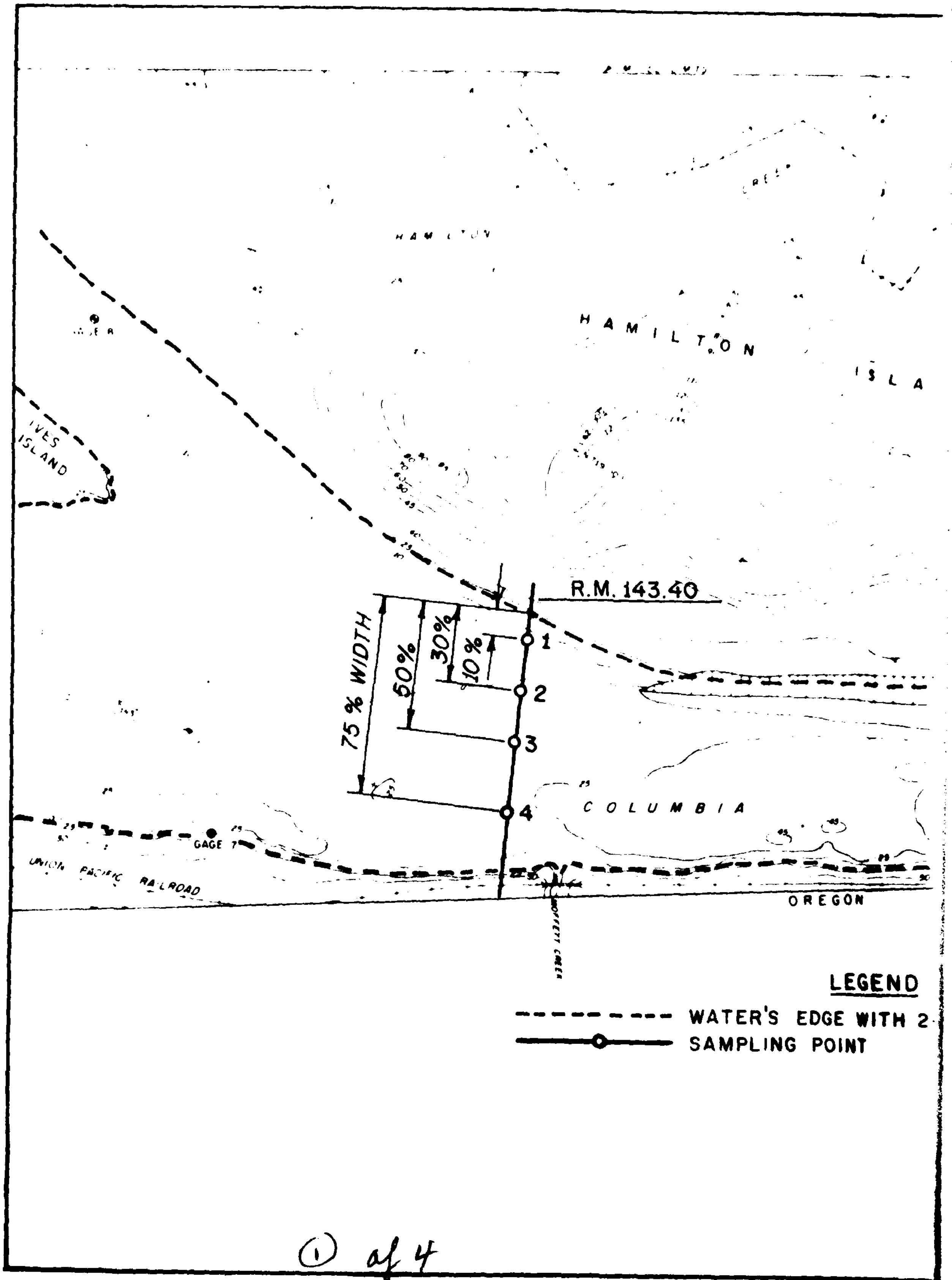
AS-BUILT APPROACH

APPROACH FLOW CONDITIONS

SITE C-3 POWERHOUSE

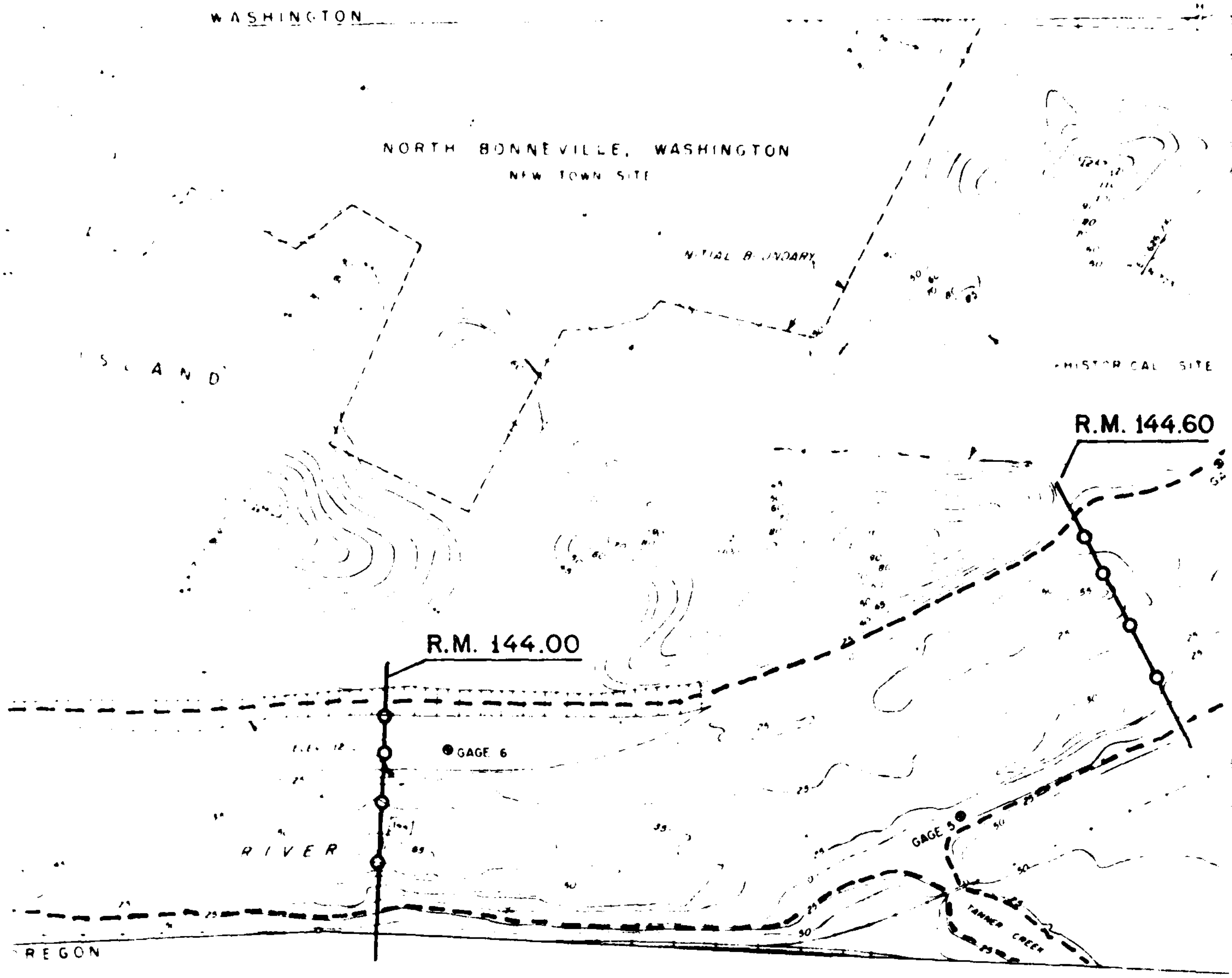
RIVER DISCHARGES 360000 AND 420000 CFS

PLATE 51



① of 4

PLATE 52



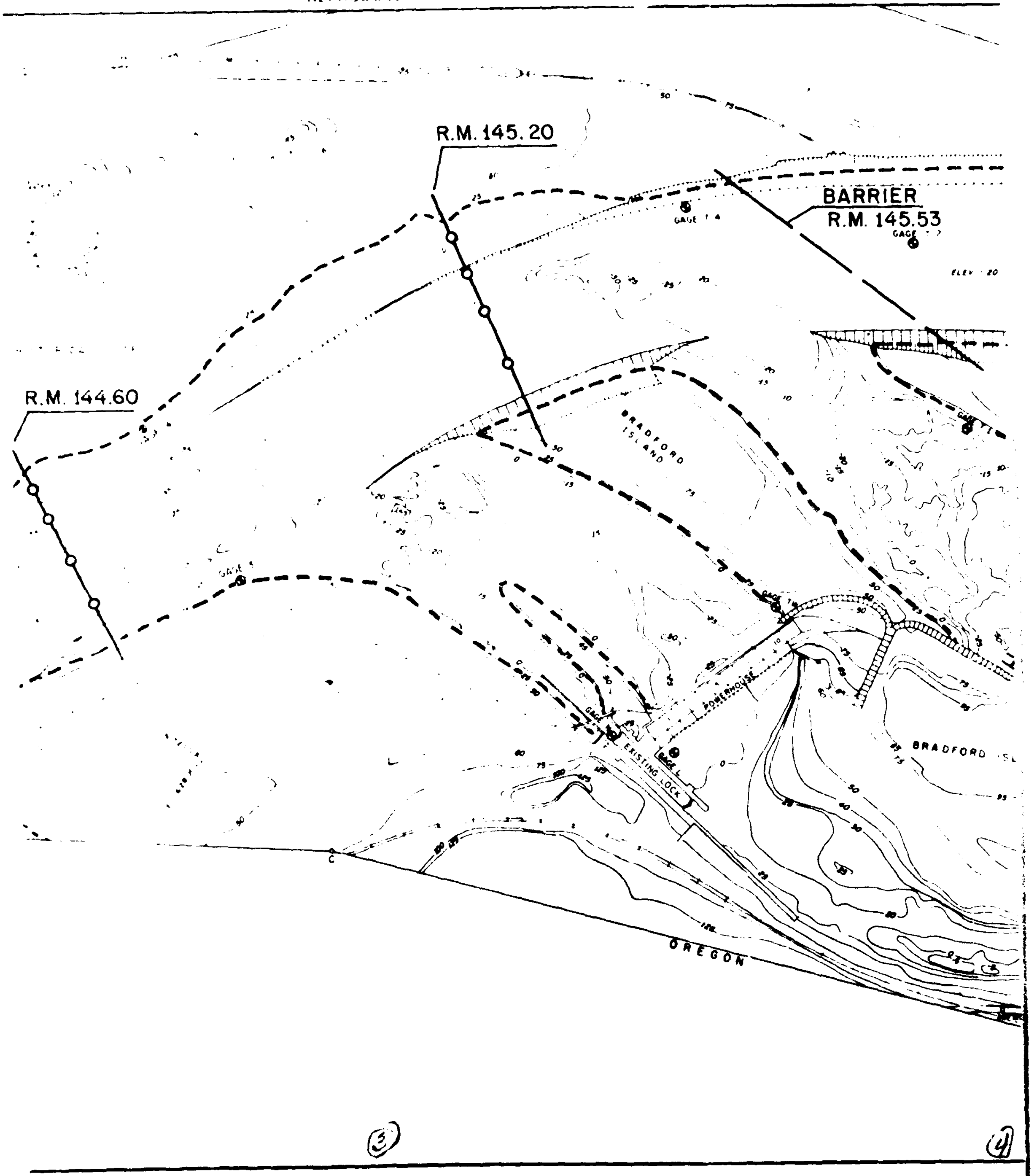
LEGEND

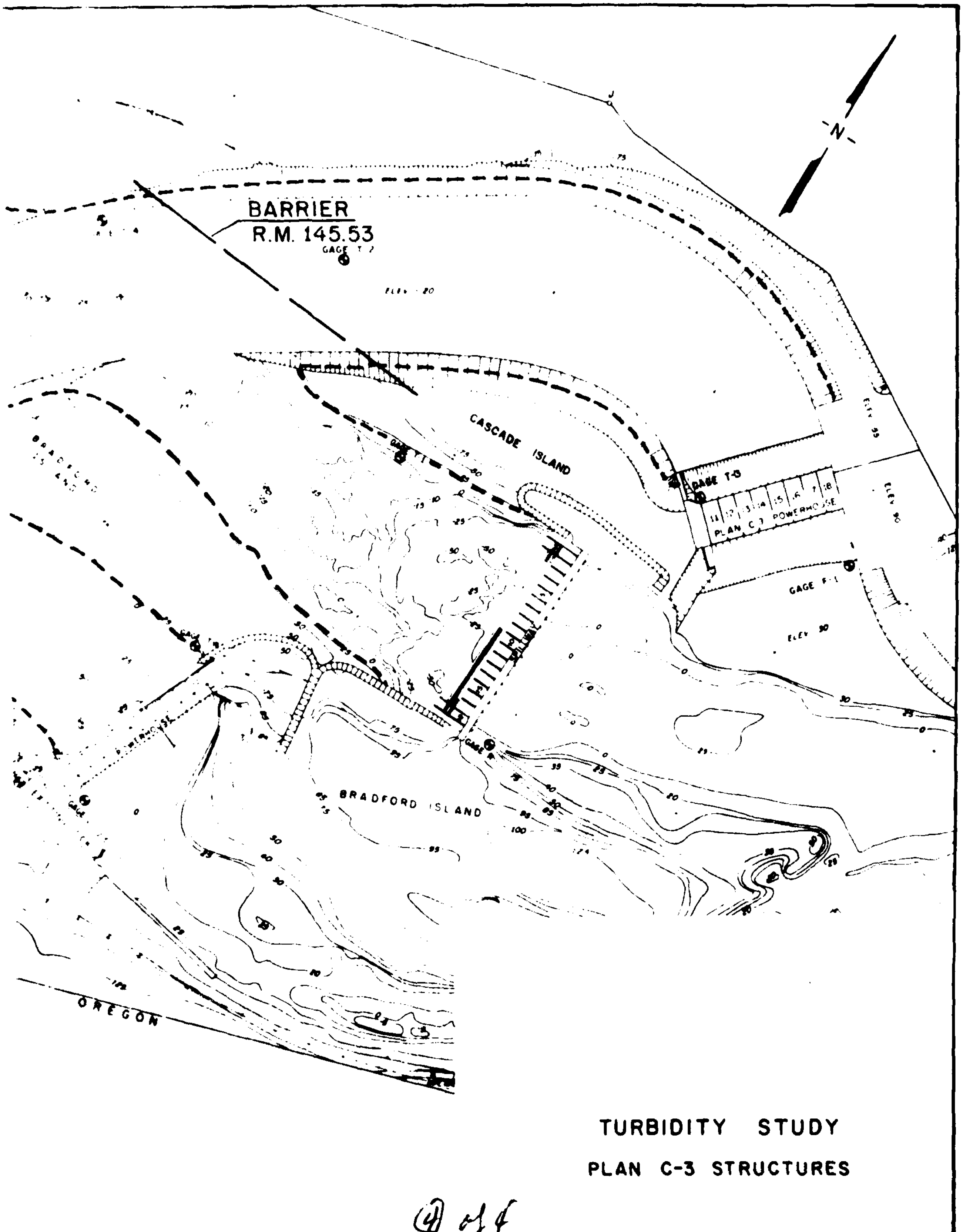
EDGE WITH 240 000 CFS

; POINT

SCALE

0 500 1000 1500 2000 FT

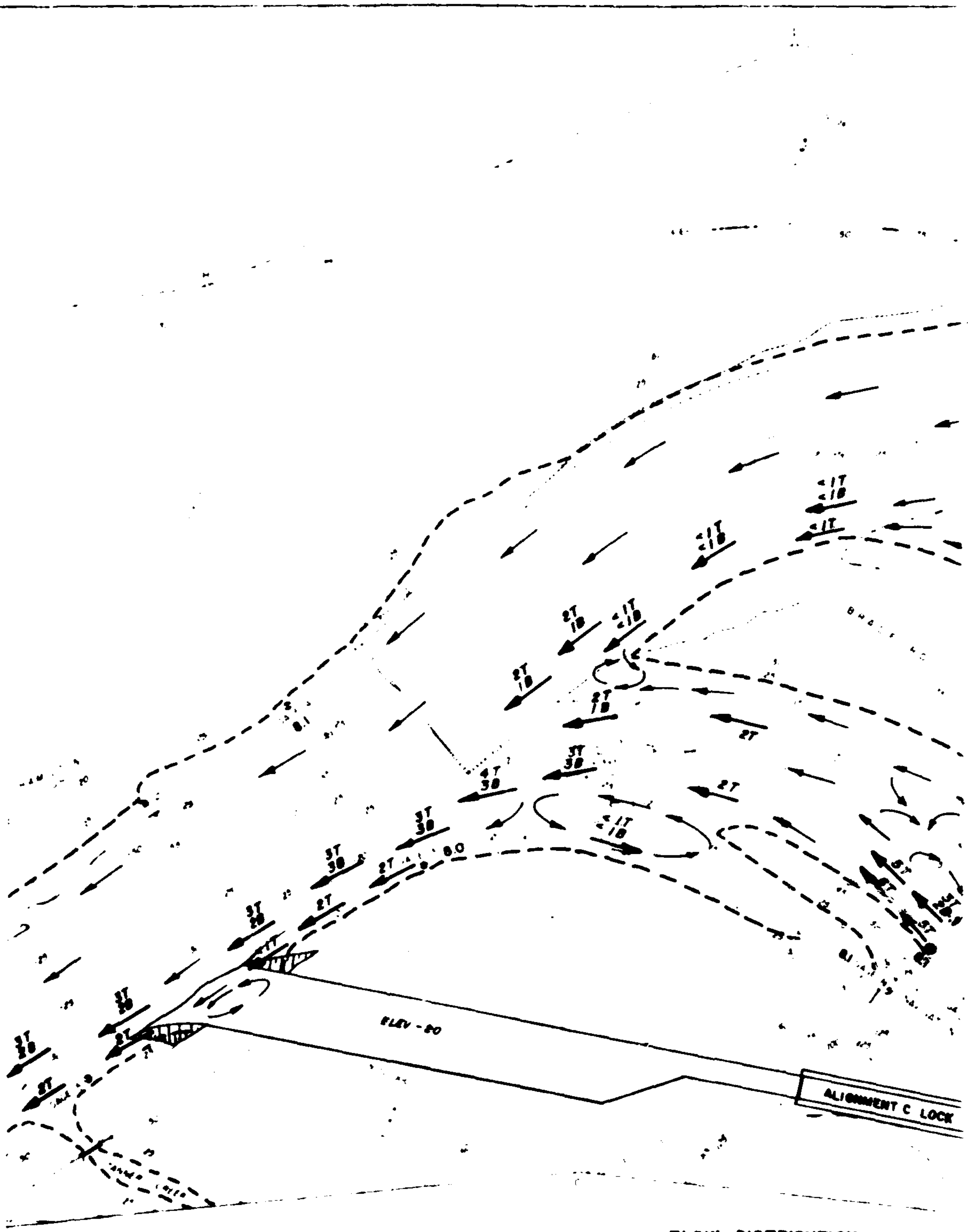

R.M. 145.20
BARRIER
R.M. 145.53
R.M. 144.60
BRADFORD ISLAND
POWERHOUSE
EXISTING LOCK
OREGON
3
4



TURBIDITY STUDY

PLAN C-3 STRUCTURES

4 of 4



LEGEND

- 4 — VELOCITIES IN FPS
- T — 5-FT DEPTH
- B — 5 FT ABOVE BOTTOM
- POWERHOUSE UNIT OFF
- SURFACE FLOW DIRECTION

FLOW DISTRIBUTION

SITE C-3 POWERHOUSE	36 000
SPILLWAY BAYS 1 AND 18	2 400
SPILLWAY BAYS 2 TO 17	0
EXISTING POWERHOUSE	34 100
FISH FACILITIES	7 800

1

Plate 53

FLOW DISTRIBUTION

POWERHOUSE	36 000 CFS
;AYS 1 AND 18	2 400 CFS
BAYS 2 TO 17	CLOSED
?OWERHOUSE	34 100 CFS
ITIES	7 600 CFS

SCALE

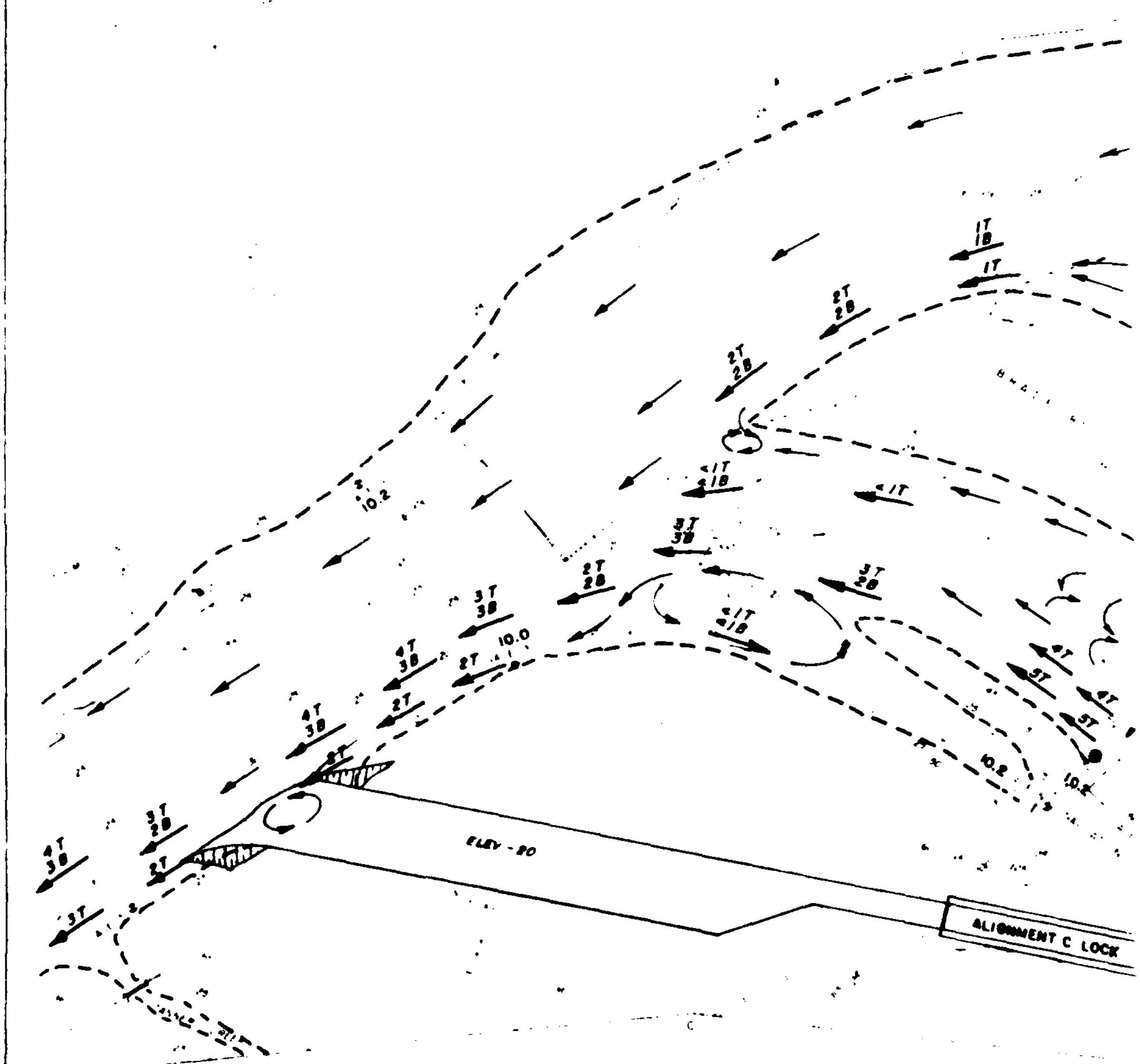
(2)

VELOCITIES

RIVER DISCHARGE 80 000 CFS

3 of 3

PLATE 53



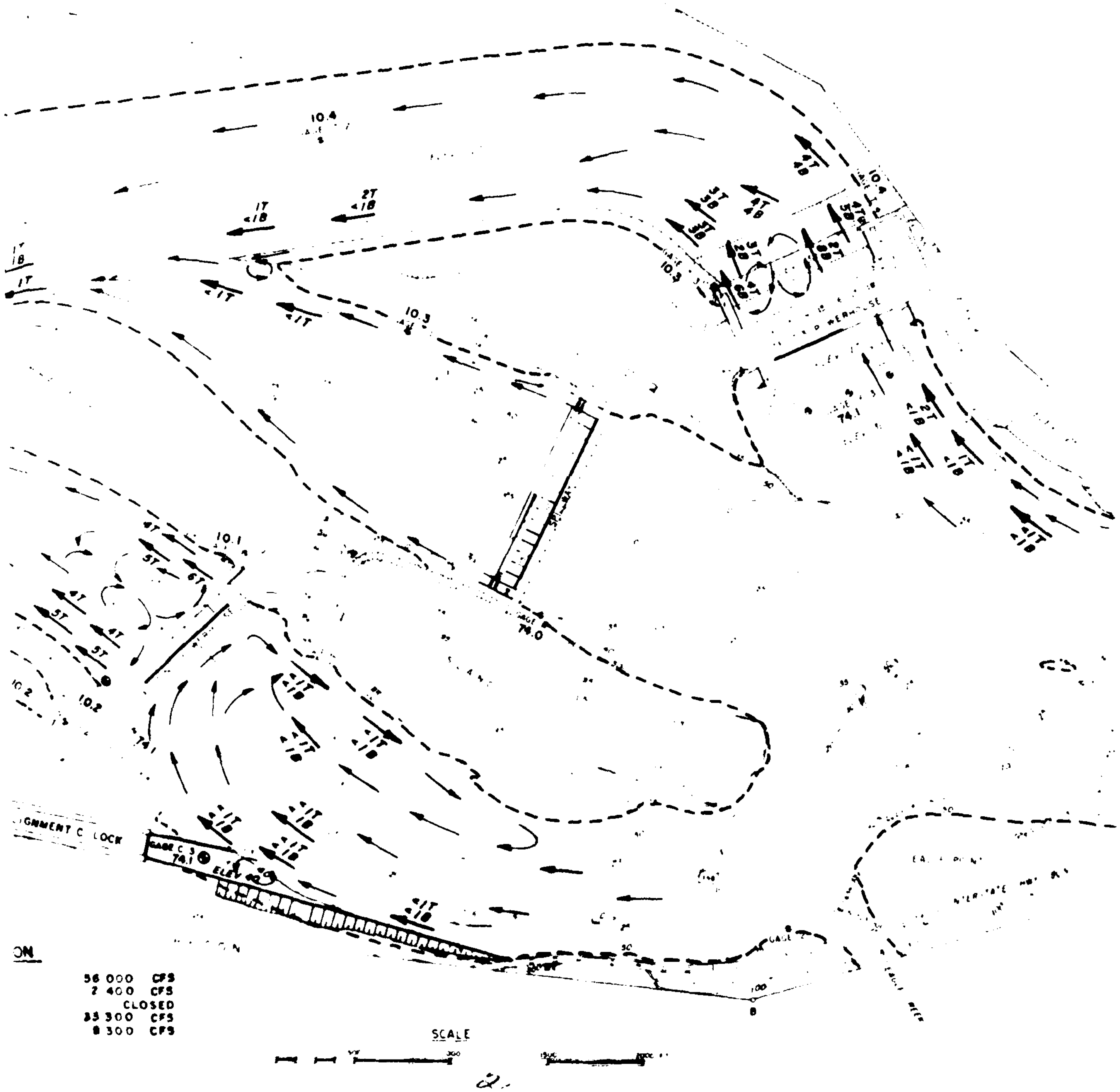
LEGEND

- 4 VELOCITIES IN FPS
- T 5-FT DEPTH
- B 5 FT ABOVE BOTTOM
- POWERHOUSE UNIT OFF
- SURFACE FLOW DIRECTION

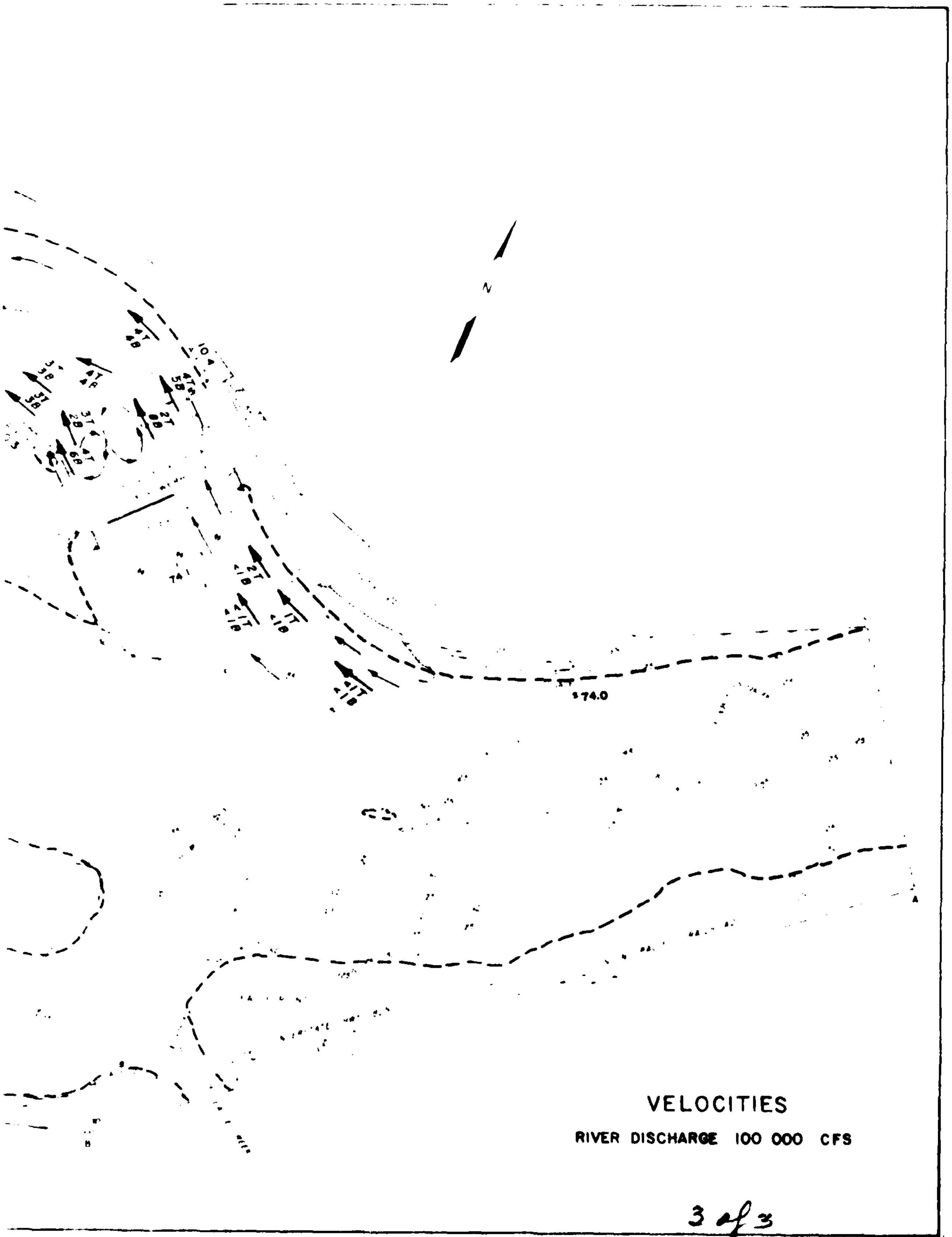
FLOW DISTRIBUTION

SITE C-3 POWERHOUSE	56 000
SPILLWAY BAYS 1 AND 18	2 400
SPILLWAY BAYS 2 TO 17	CL
EXISTING POWERHOUSE	33 300
FISH FACILITIES	8 300

Plate 54



10.4
10.3
10.1
10.2
74.1
74.0
GAGE C-3
GNMENT C LOCK
ON
56 000 CFS
2 400 CFS
CLOSED
33 300 CFS
8 300 CFS
SCALE



VELOCITIES

RIVER DISCHARGE 100 000 CFS

3 of 3

PLATE 54

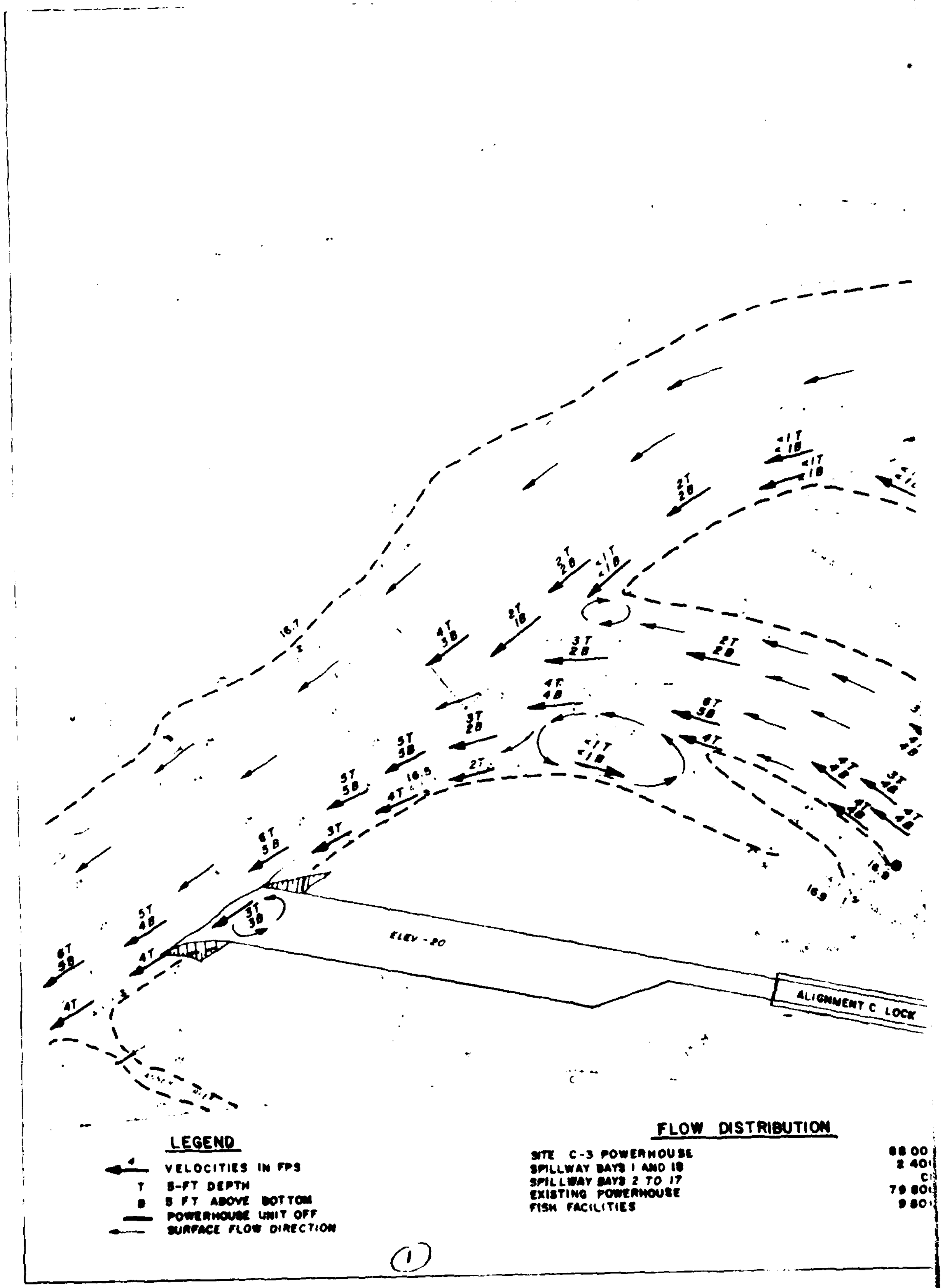
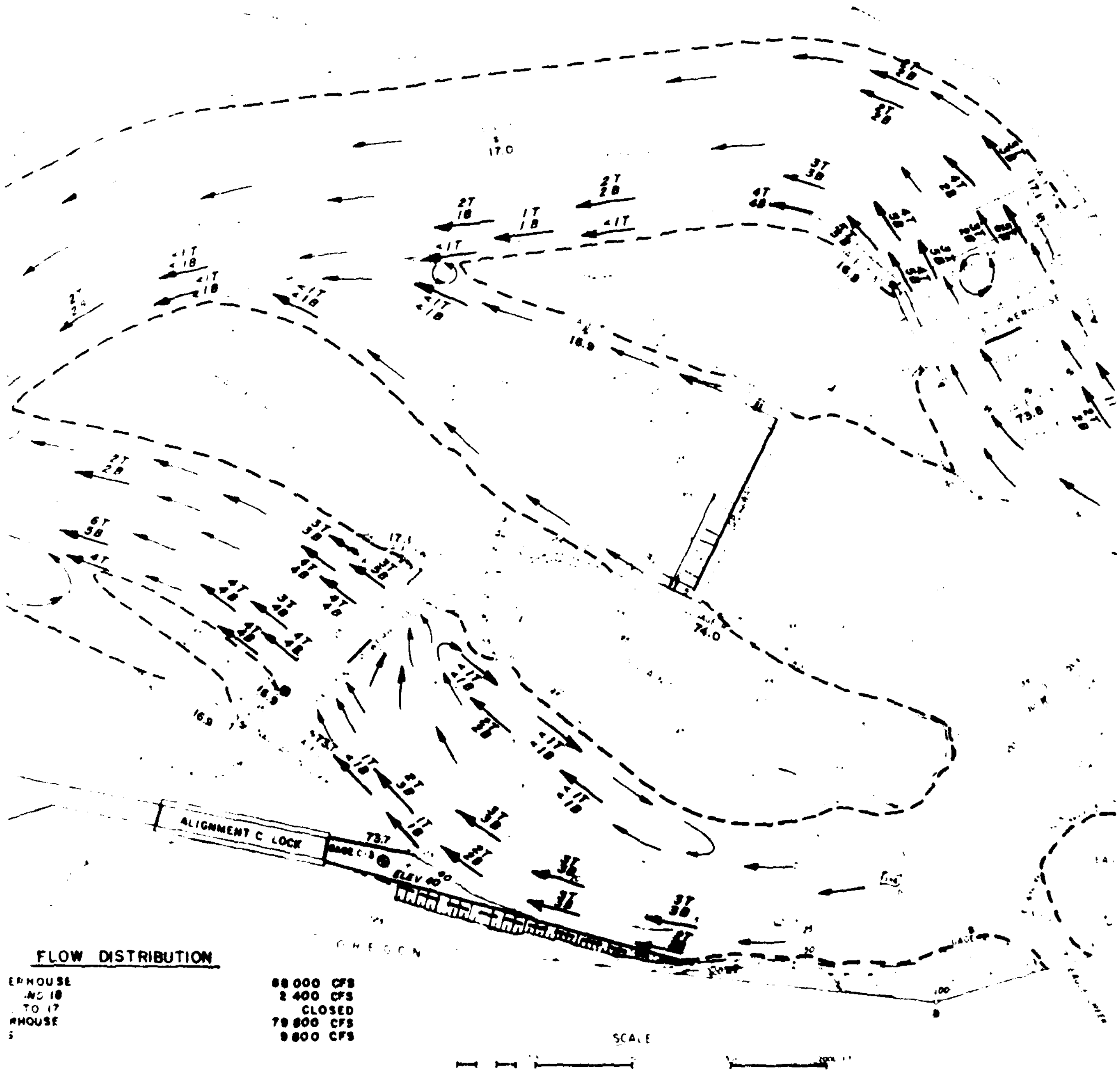
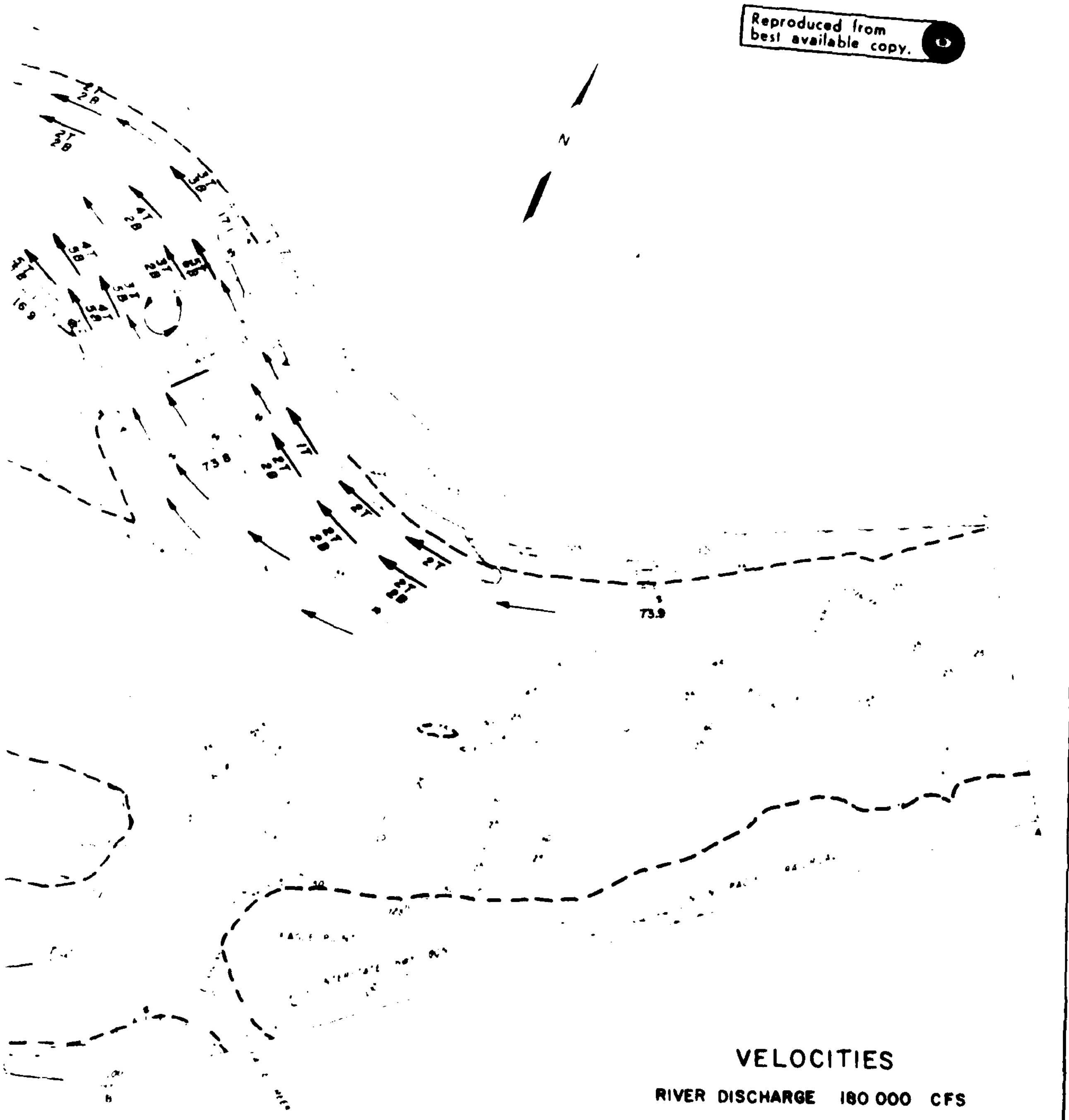

ELEV -20
ALIGNMENT C LOCK
LEGEND
VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM
POWERHOUSE UNIT OFF
SURFACE FLOW DIRECTION
FLOW DISTRIBUTION
SITE C-3 POWERHOUSE
SPILLWAY BAYS 1 AND 18
SPILLWAY BAYS 2 TO 17
EXISTING POWERHOUSE
FISH FACILITIES
(1)

Plate 55


FLOW DISTRIBUTION
88 000 CFS
2 400 CFS
CLOSED
79 800 CFS
9 800 CFS
ALIGNMENT C LOCK
73.7
74.0
73.8
17.0
16.9
SCALE

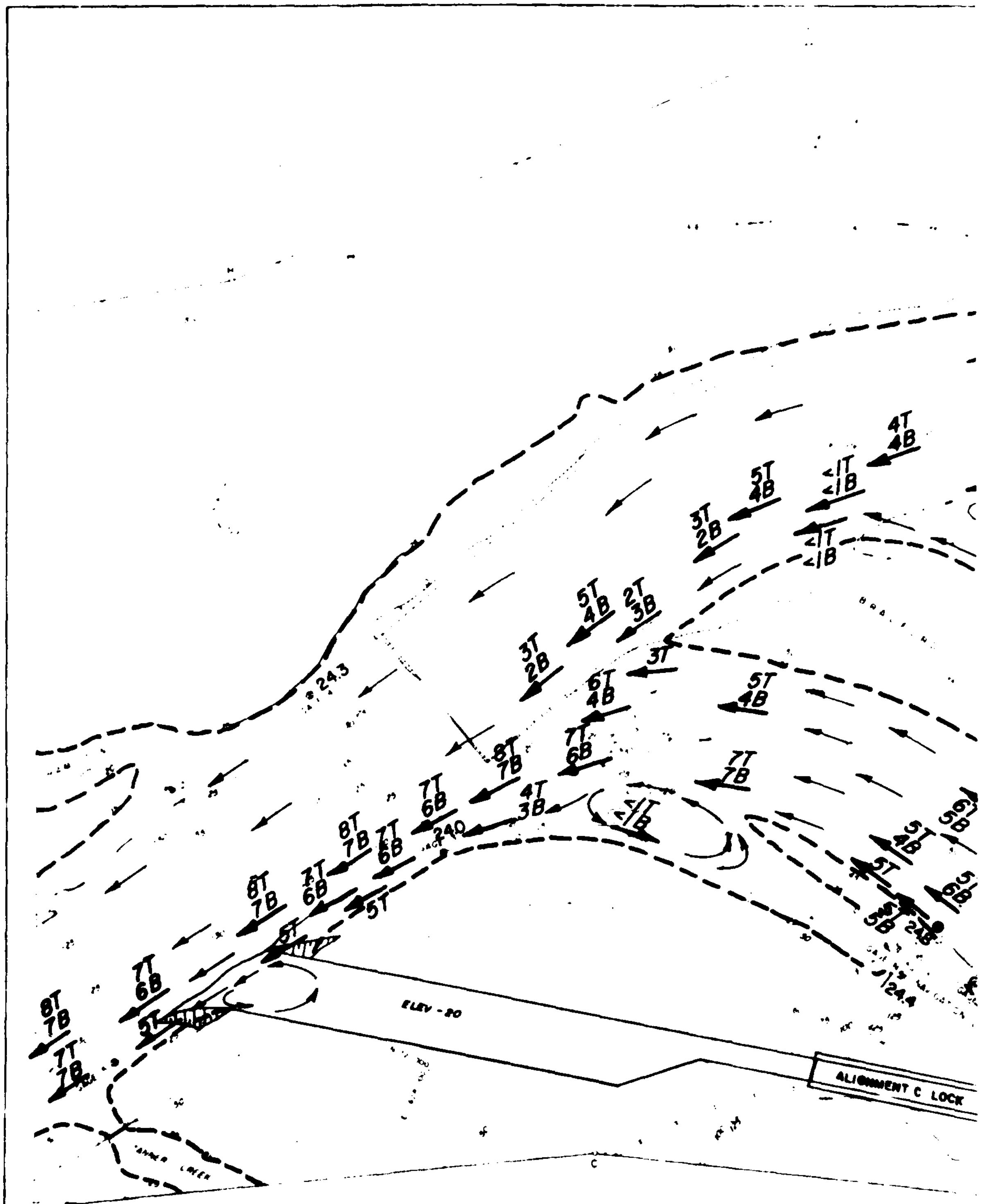


VELOCITIES

RIVER DISCHARGE 180 000 CFS

3 of 3

PLATE 55



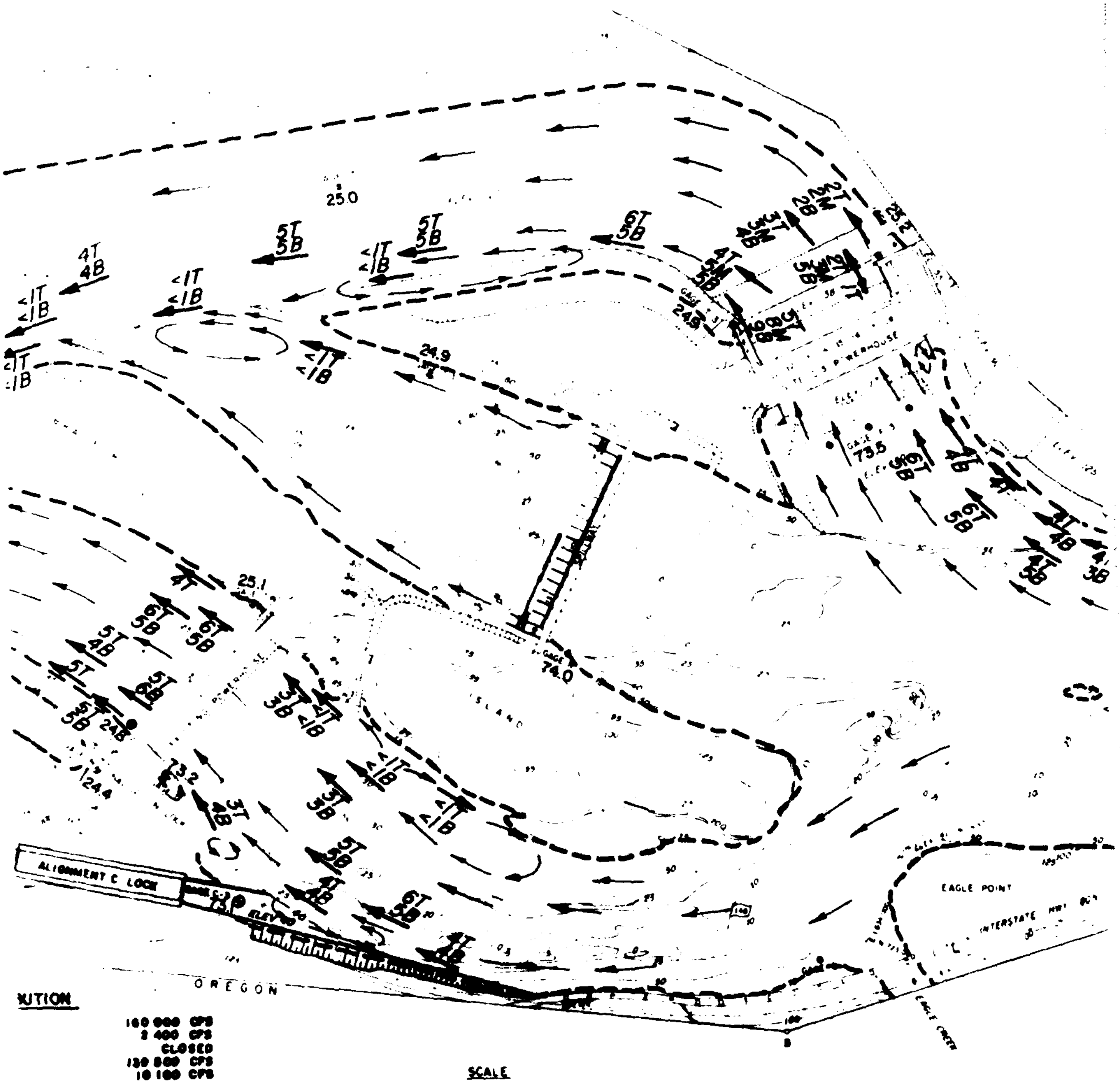
LEGEND

4 (arrow)	VELOCITIES IN FPS
T	5-FT DEPTH
B	5 FT ABOVE BOTTOM
	POWERHOUSE UNIT OFF
	SURFACE FLOW DIRECTION

FLOW DISTRIBUTION

SITE C-3 POWERHOUSE 11 thru 18	180 00
SPILLWAY BAYS 1 AND 18	2 40
SPILLWAY BAYS 2 TO 17	Cl
EXISTING POWERHOUSE 1 thru 10	139 50
FISH FACILITIES	10 10

Plate 56



UTION

160 000 CFS
2 400 CFS
CLOSED
130 800 CFS
10 100 CFS

SCALE

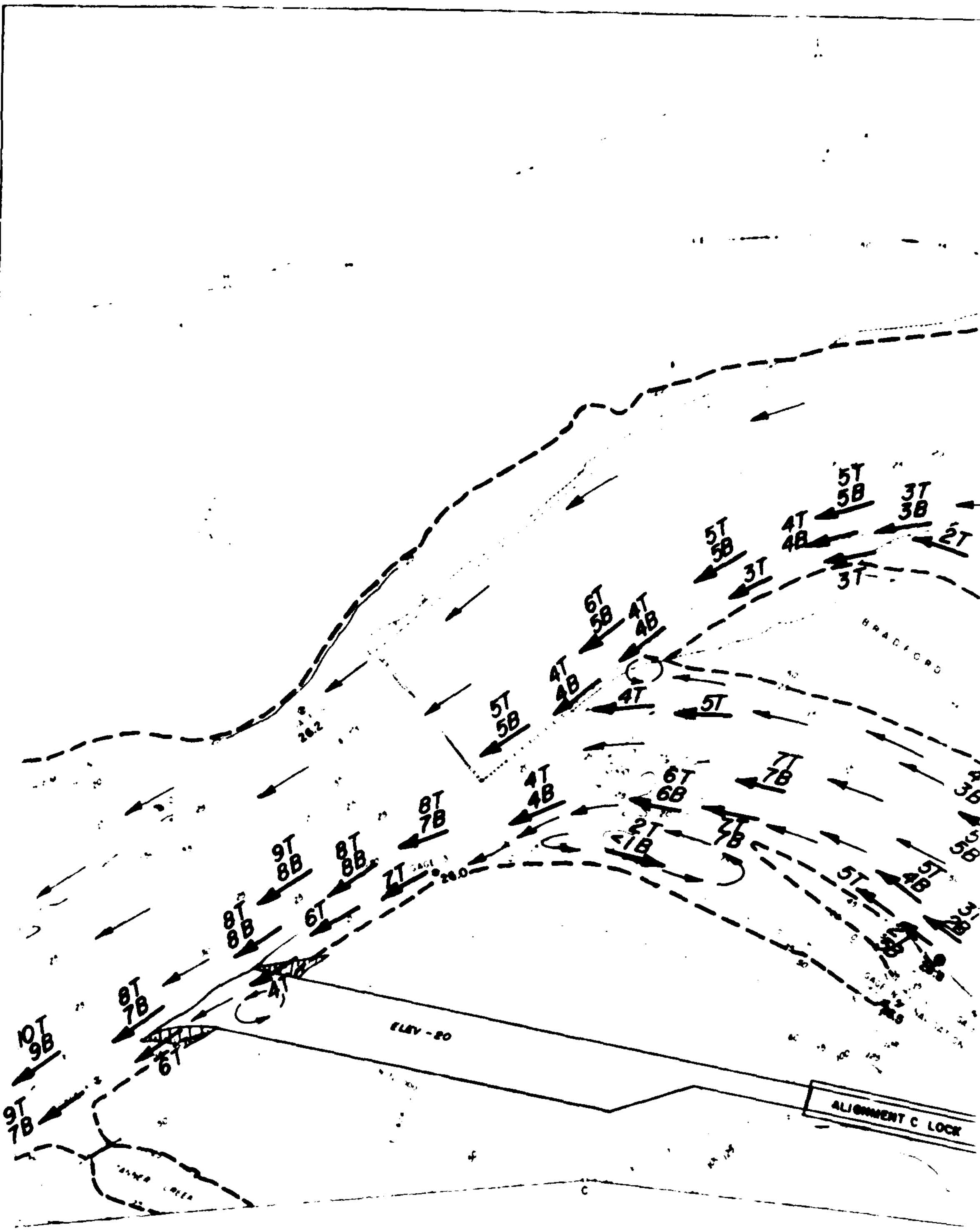
2

VELOCITIES

RIVER DISCHARGE 312 000 CFS

3 of 3

PLATE 56



LEGEND

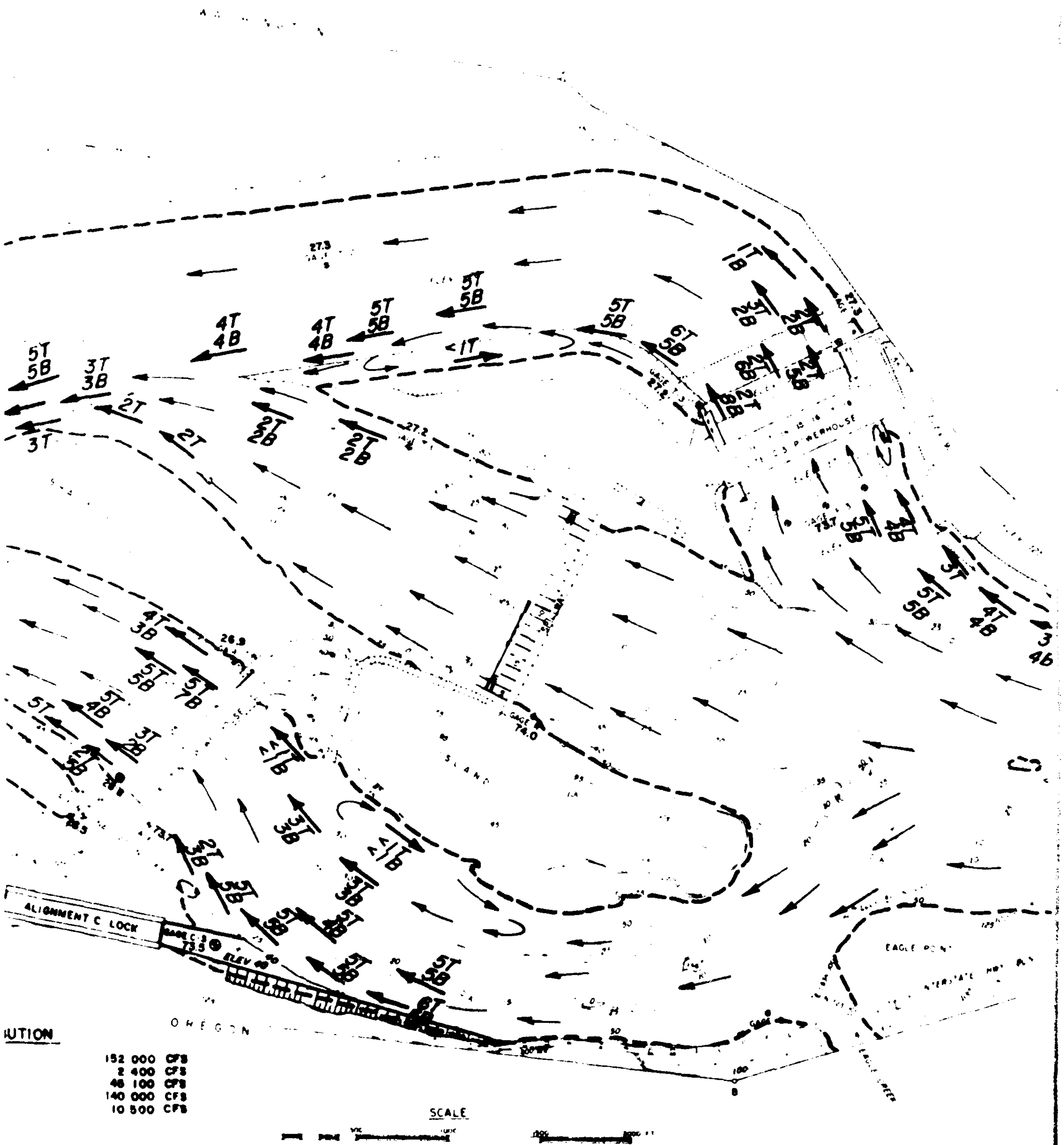
- VELOCITIES IN FPS
- T 5-FT DEPTH
- B 5 FT ABOVE BOTTOM
- POWERHOUSE UNIT OFF
- SURFACE FLOW DIRECTION

FLOW DISTRIBUTION

SITE C-3 POWERHOUSE 11 thru 18	152 000
SPILLWAY BAYS 1 AND 18	2 400
SPILLWAY BAYS 2 TO 17	48 100
EXISTING POWERHOUSE 1 thru 10	140 000
FISH FACILITIES	10 500

1

Plate 57

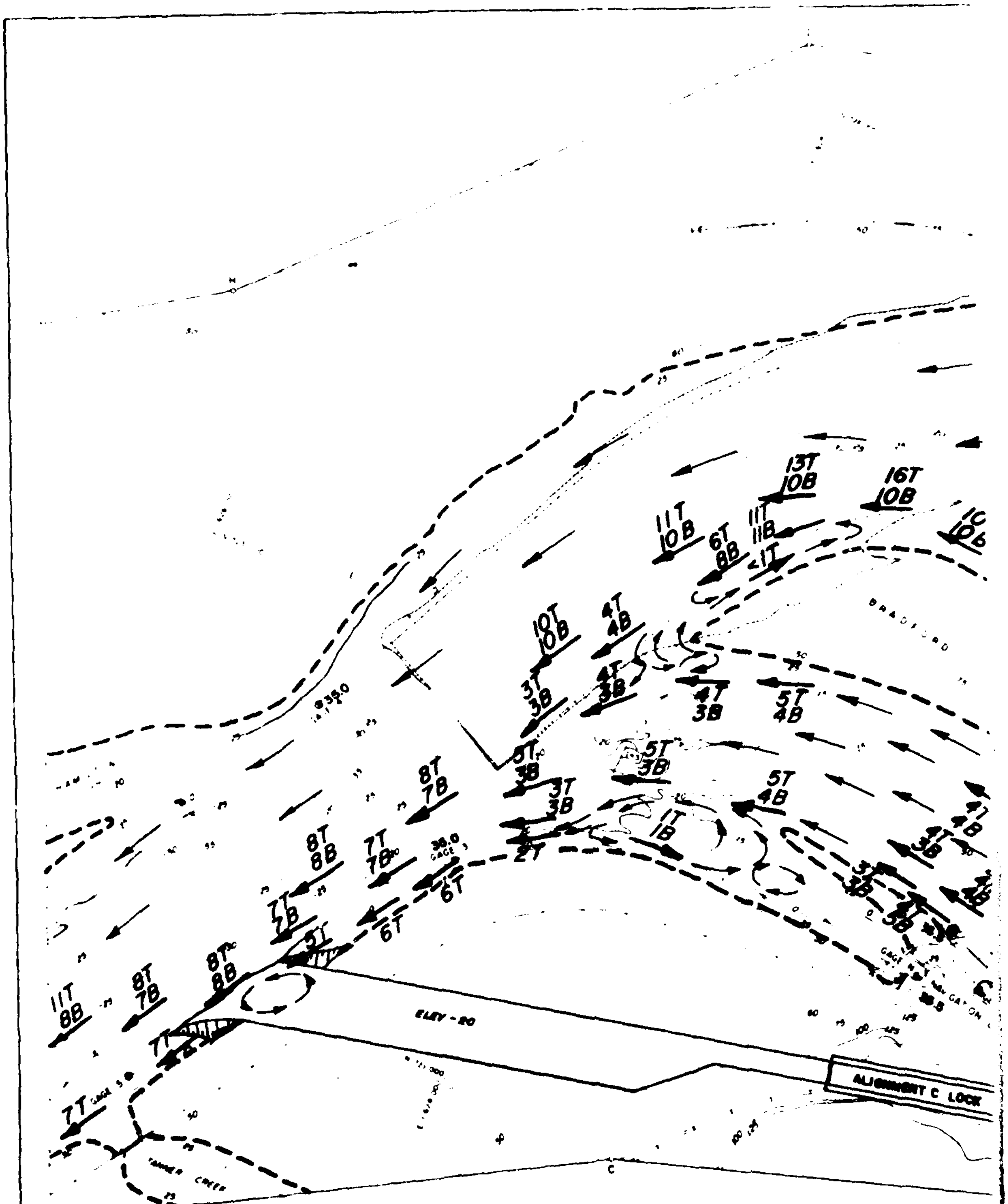

ALIGNMENT C LOCK
OREGON
EAGLE POINT
SCALE
UTION
152 000 CFS
2 400 CFS
46 100 CFS
140 000 CFS
10 500 CFS

2

VELOCITIES

RIVER DISCHARGE 350 000 CFS

3 of 3



LEGEND

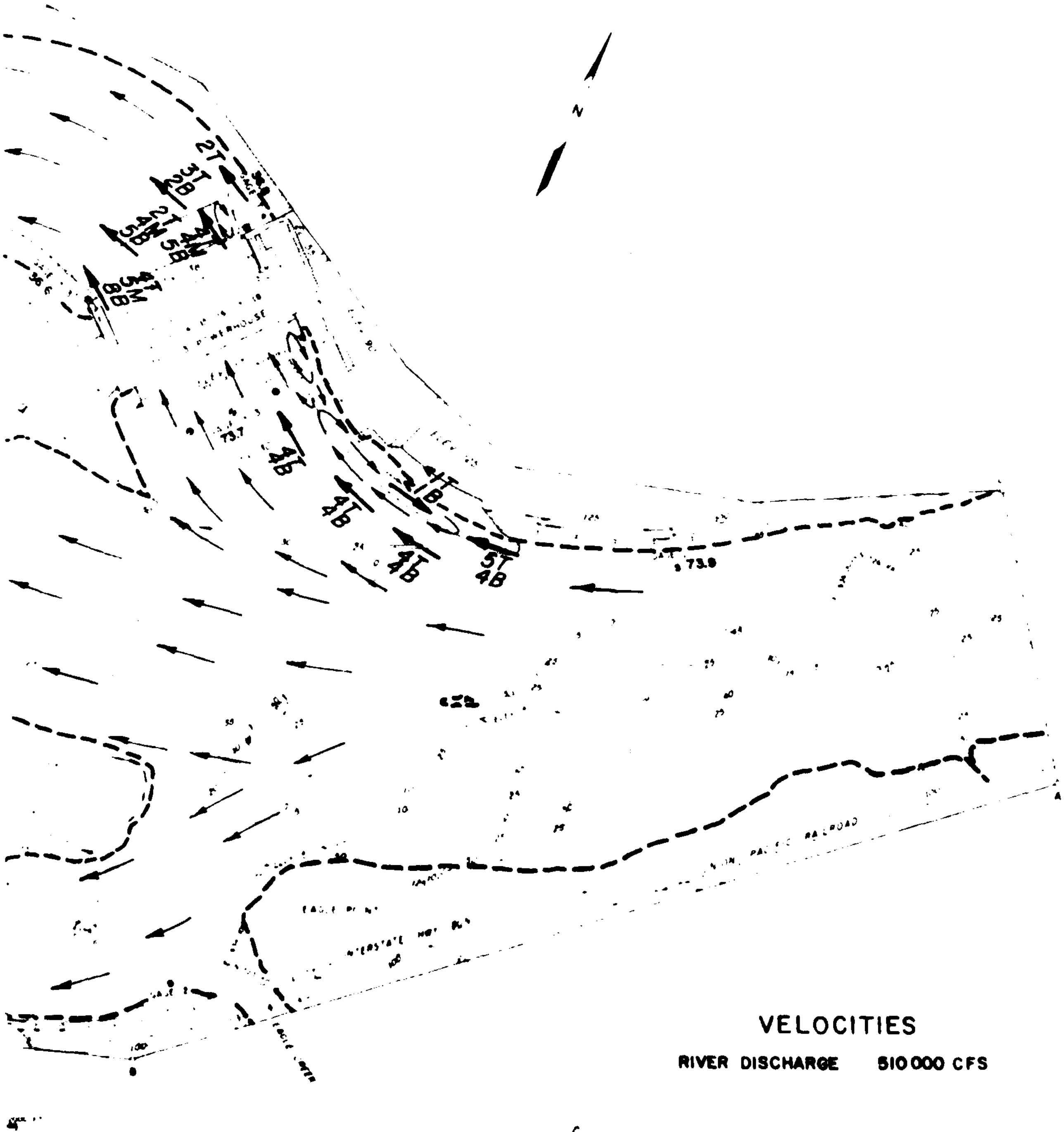
- VELOCITIES IN FPS
- T 5-FT DEPTH
- B 5 FT ABOVE BOTTOM
- POWERHOUSE UNIT OFF
- SURFACE FLOW DIRECTION

FLOW DISTRIBUTION

SITE C-3 POWERHOUSE	11 thru 18	144 00
SPILLWAY BAYS 1 AND 18		2 40
SPILLWAY BAYS 2 TO 17		222 80
EXISTING POWERHOUSE	1 thru 10	130 00
FISH FACILITIES		10 80

Plate 58

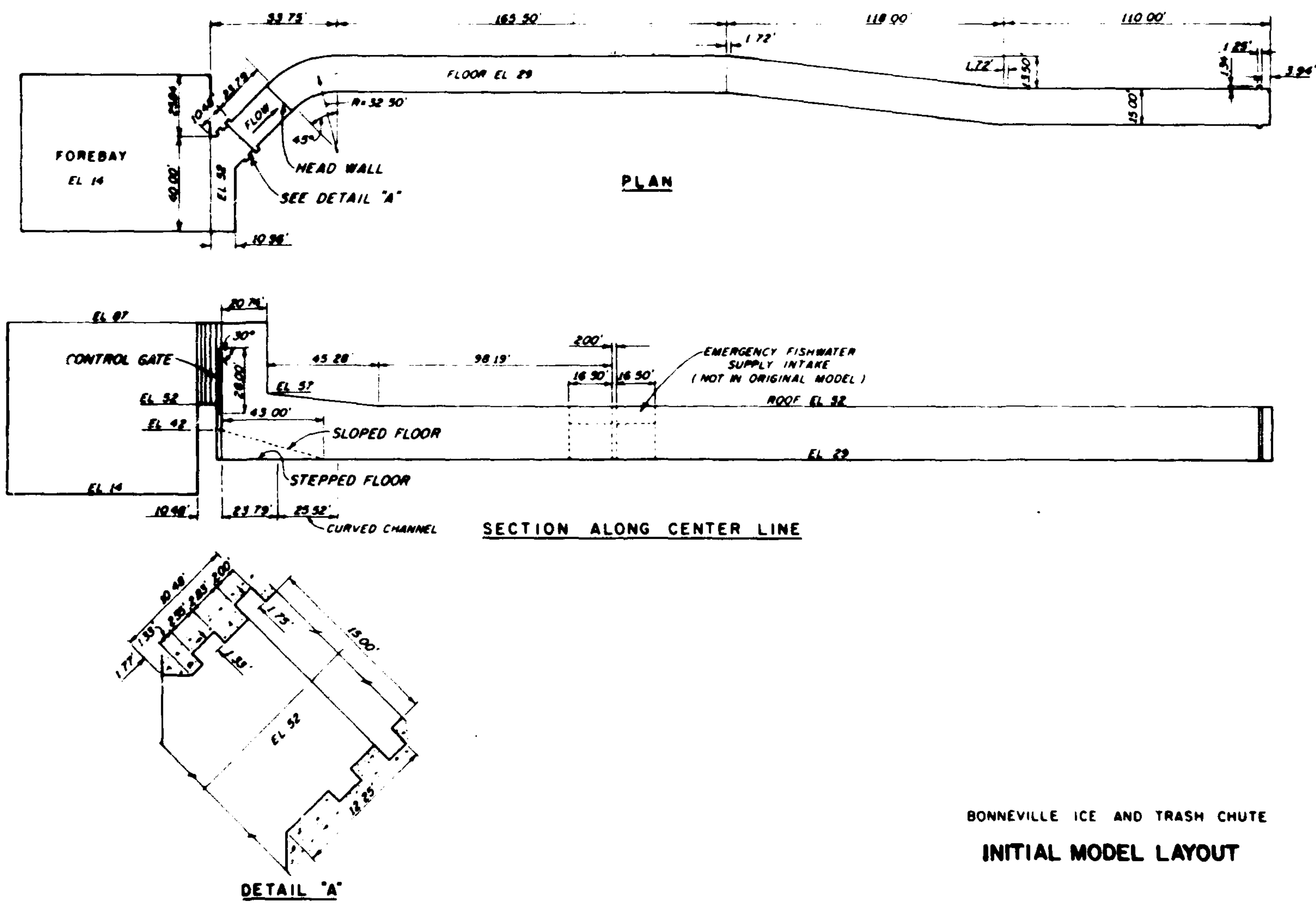

WASHINGTON
OREGON
ALIGNMENT C LOCK
POWERHOUSE
EAGLE POINT
INTERSTATE HWY
GAGE 2
74.0
73.7
UTION
144 000 CFS
2 400 CFS
222 800 CFS
130 000 CFS
10 800 CFS
SCALE



VELOCITIES

RIVER DISCHARGE 510 000 CFS

3 of 3



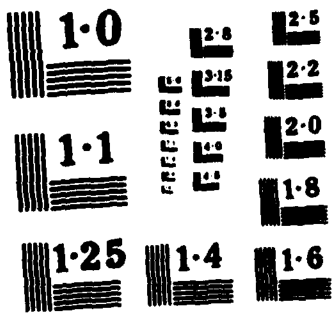
BONNEVILLE ICE AND TRASH CHUTE

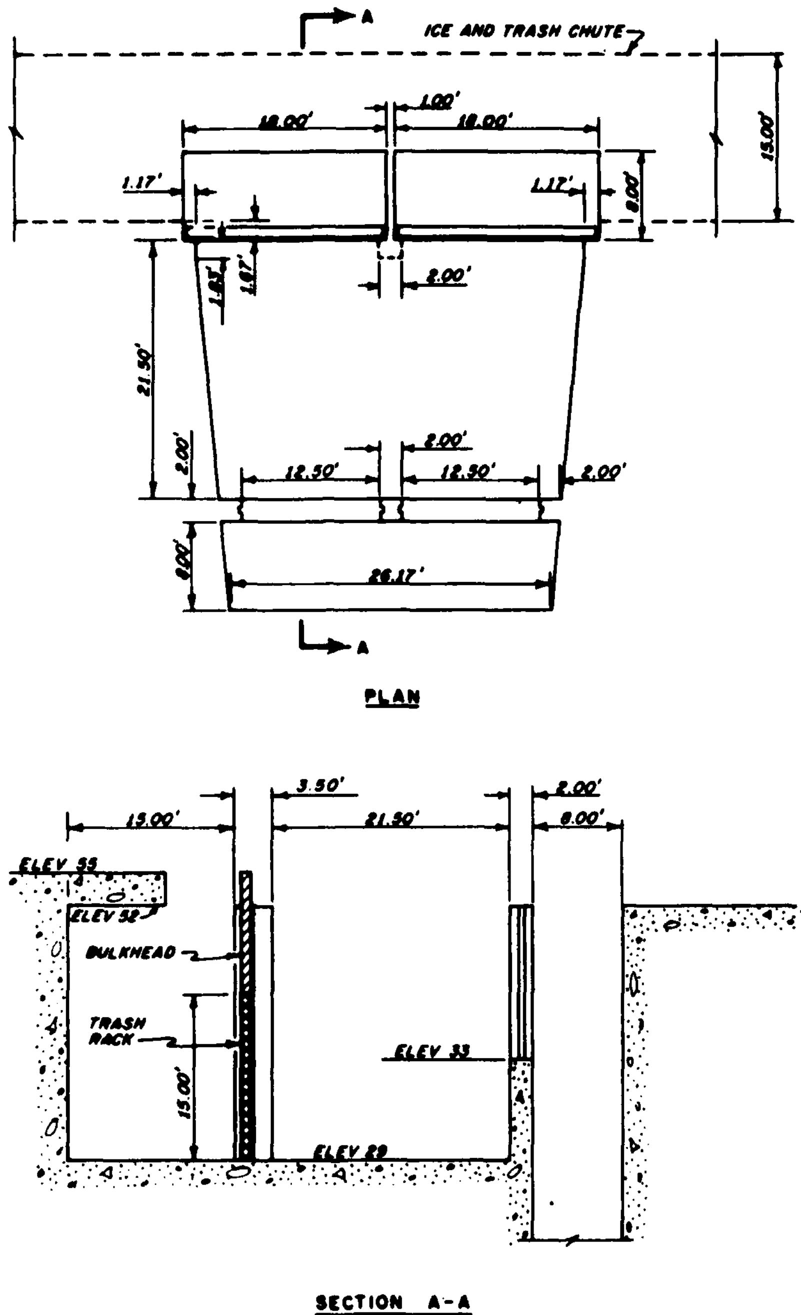
INITIAL MODEL LAYOUT

AD A146 974 BONNEVILLE SECOND POWERHOUSE COLUMBIA RIVER OREGON AND WASHINGTON HYDRAUL..(U) ARMY ENGINEER DIV NORTH PACIFIC BONNEVILLE OR DIV HYDRAULIC L.. W CONBERE AUG 84 3/3

UNCLASSIFIED TR 137 1 F/G 10/2 NL

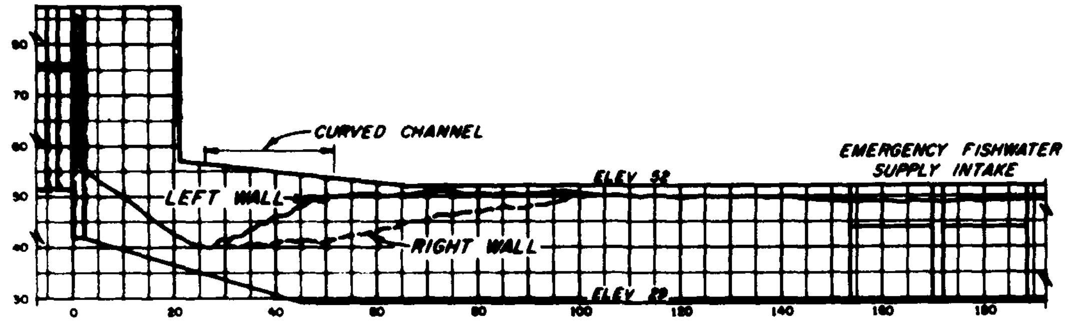
END
DATE FILMED
10 84


1·0
2·8
2·5
2·2
1·1
2·0
1·8
1·25
1·4
1·6

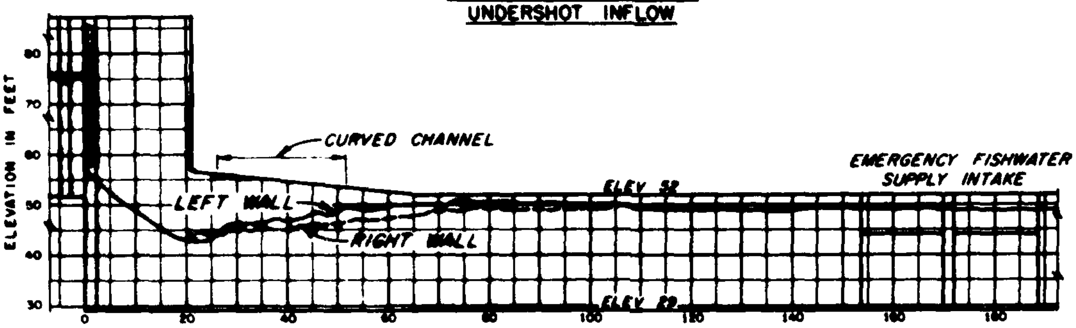


BONNEVILLE ICE AND TRASH CHUTE

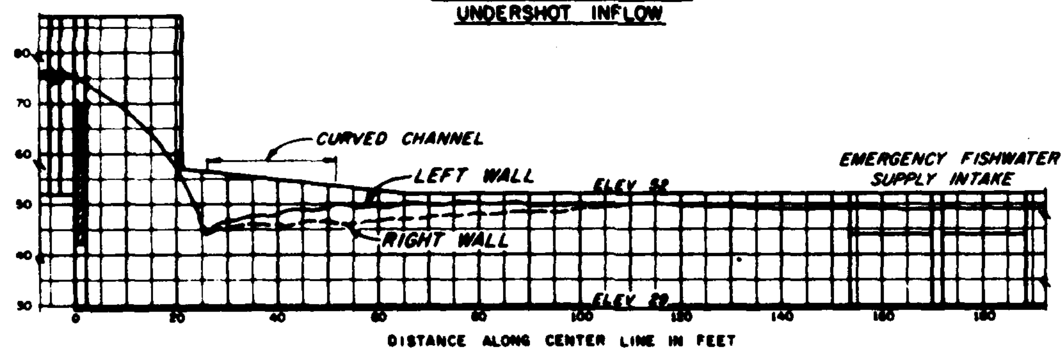
EMERGENCY FISHWATER SUPPLY INTAKE



SLOPED CHUTE FLOOR
UNDERSHOT INFLOW



STEPPED CHUTE FLOOR
UNDERSHOT INFLOW

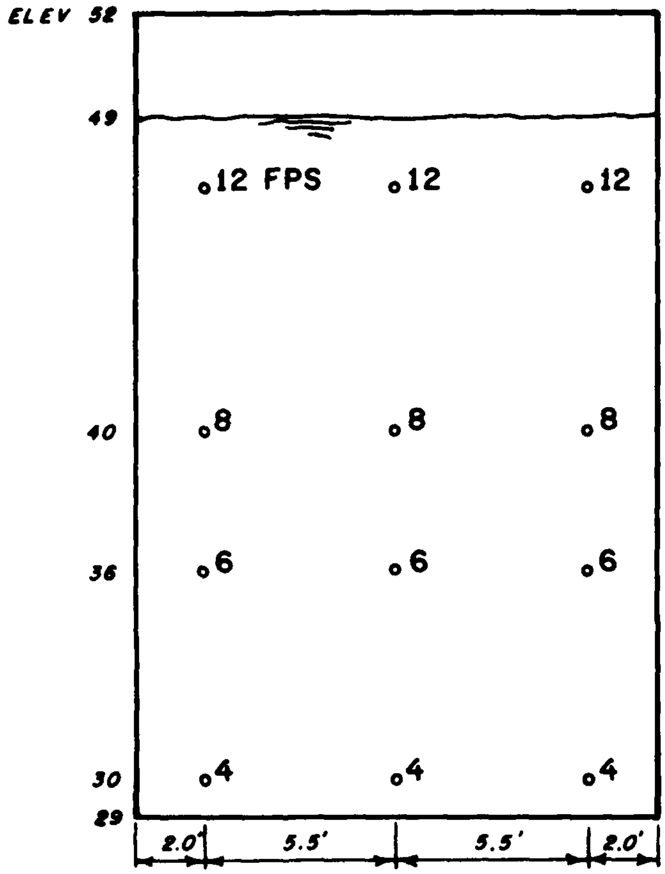


STEPPED CHUTE FLOOR
OVERSHOT INFLOW

BONNEVILLE ICE AND TRASH CHUTE

WATER SURFACE PROFILES

DISCHARGE 2200 CFS



NOTES

1. FLOW DEPTH CONTROLLED BY STOP LOGS AT DOWNSTREAM END OF CHUTE.
2. ALL FLOW IN CHUTE. NO WITHDRAWAL AT INTAKE.

BONNEVILLE ICE AND TRASH CHUTE

AVERAGE VELOCITIES AT UPSTREAM EDGE OF FISHWATER INTAKE

DISCHARGE 2200 CFS

PLATE 63